MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

INDIA.

VOL. XIV.

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PREFACE.

UNDER instructions from the Superintendent of the Geological Survey of India, I arrived in the Punjab in the cold weather of 1869-70, and commenced the examination of the Salt Range Mountains. During the next season and part of the one which followed I was entirely occupied with this work. The fossil collections which I had from time to time forwarded to head-quarters ultimately suggested a palæontological examination of the strata in the field, and Dr. W. Waagen, then on the staff of the Geological Survey, was deputed to carry this out. He reached the Salt Range after the whole of the region had been mapped, and after its various geological groups had been arranged, according to their generally well-marked petrological features. I accompanied him, and we visited together several of the instructive sections. After this, he, by himself, devoted many weeks to a close reconnoissance of the Range, noting various sections in detail, largely increasing the fossil collections, and observing the demarcation of the groups indicated by these fossils.

This examination caused no alteration in the boundary lines which I had drawn, nor in the general arrangement of the groups, but it enabled the geological positions of certain highly fossiliferous formations, such as the triassic and jurassic, and the upper limits of the carboniferous, to be more definitely established. It led to Dr. Waagen's discovery of (unique) carboniferous ammonites, and to his suggestion

that one of the groups in the eastern part of the Range, containing many ill-preserved shells, as also some doubtful beds below the nummulitic, might be cretaceous; while another unfossiliferous group was thought by him to be possibly triassic. About the probable places of one or two other unfossiliferous groups he expressed doubt.

Shortly before making the first draft of the present Memoir, I had had the advantage of frequent discussions upon the local geology with Dr. Waagen, who further gave me some field notes detailing certain sections which he had visited after I left him. I have, in several instances, used these notes in preference to my own, because they are more detailed, and because they possess the advantage that the most characteristic and abundant fossils have been identified by a competent palæontologist.

At one time it was intended to have made this Salt Range Memoir a joint production by Dr. Waagen and myself, and to have added a description of the palæontology and a comparison between the geology and that of some European regions, together with plates and figures to illustrate both the geology and palæontology of the district; but Dr. Waagen's labours upon the fossil Cephalopoda of Kach, followed by his long absence on sick-leave, prevented the design, of which he would have written the palæontological portion, from being carried out. His early retirement from the Survey in ill-health before he could work out the Salt Range collections or contribute towards the manuscript of a joint report, beyond what will be acknowledged in the following pages, and a few marginal notes on my preliminary report, has left to

me the rather difficult task of re-casting alone matter intended for a joint publication.

The originality of this Memoir will, in one aspect, be necessarily limited, when the long list of previous writers upon the geology of the Salt Range is considered. That the Range contained carboniferous, jurassic, or oolitic, possibly triassic, eocene, and perhaps miocene, formations, has long been known from former publications; but the addition to these of an ascertained silurian zone above the salt, and a new arrangement of all of its groups, have resulted from the operations of the Geological Survey.

The bulk of the following report has lain for some years in manuscript awaiting publication. This has been postponed for various reasons, the chief of which I have mentioned. The extensive fossil collections from the district, when I last saw them, had been but partially prepared for examination, and though I can only give such provisional identifications as were afforded by our lamented colleague Dr. Stoliczka and by Dr. Waagen, it is satisfactory to know that the palæozoic and secondary fossils have been forwarded lately to Dr. Waagen himself for description.

In preparing this Memoir for publication, I have to thank Mr. W. T. Blanford for much assistance in reading the proofs; and whatever success has attended the reproduction of my landscape illustrations is largely due to their treatment by Mr. Schaumburg, the Artist of the Survey.

A. B. WYNNE.

CAMP HAZARA,
November 1877.

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22. VERCHERE, DR. A. M.—Kashmir, the Western Himalaya, and Afghan Mountains. Jl. A. S. B., Vols. XXXV & XXXVI. 1866-67

23. BADEN-POWELL, MR.—Economic products of Punjab, Vol. I, pp. 13, 69, 130, &c. . . . 1868

24. WYNNE, A. B.—Geology Mt. Tilla. Records Geol. Sur. Ind., Vol. III. 1870

25. LYMAN, B. S.—General Report on Punjab oil-lands. Government Press, Lahore, D. P. W. 1870

26 WARTH, DR. H.—Geology Khewra Salt Range. Appendix, Report, Administration, Inland Customs Department, Official year 1869-70 1871

27 HICKIE, M.,—Pamphlet on customs, quoted by Dr. Warth in above.

28 HICKIE, CORNELIUS—Analysis of Salt Range salt quoted by Dr. Warth ditto.

29 LYMAN, B. S.,—Topography of Punjab oil regions. Tran. Amer. Phil. Soc., Vol. XV 1872

30. MARKHAM, C.R., C. B.—On Indian Surveys, London . . 1871

31. WARTH, DR. H.—Geological descriptions, Salt Range. Report, Administration, Inland Customs Department, Appendix D, 1870-71 1872

32. WARTH, DR. AND WYNNE, A.B.,—Collection of Salt Range minerals for Vienna Exhibition. Catalogue, Lond. Sty. Office . 1873

33. OLDHAM, THOS., L.L D., &c.—Rock-Salt of Salt Range and its position. Ver. der Geol. Reichsanstalt, Vienna . . 1873

34. BLANFORD, H. F.—Physical Geography for Indian Schools, p. 133, Calcutta and London 1873

35. WYNNE, A.B.—Points in Physical Geography., Upper Punjab. Q. Jl. Geol. Soc., London, Vol. XXX, p. 61 . . 1874

36. TSCHERMAK, G.—Salt Range potash salt (translated from the *Mineralogischen Mittheilungen*, 1873, p. 135. (Rec. Geo. Sur. of India, Vol. VII, p. 64 . . . 1874

37. WYNNE, A. B.—Trans-Indus Salt Regions. Mem. Geol. Sur., Vol. XI, pp. 24, 30, &c. 1875

38. MEDLICOTT, H. B.—Sub-Himalayan series in the Jamu hills. Rec. Geol. Sur. India, Vol. IX, pt. 2, p. 49 . . . 1876

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39.	VERNEUIL, M. DE—Jl. As. Soc. Beng., No. LX, Vol. XXII, p. 267	1853
40.	FALCONER, DR. H.—Jl. As. Soc. Beng., Vol. XXIII, p. 677 .	1854
41.	DAVIDSON, THOS., F. R. S.—Q. Jl. Geol. Soc., London, Vol. XVIII. p. 25	1862
42.	KONINCK, L. DE.—Qtly. Jl. Geol. Soc., London, Vol. XIX, p. 1 .	1863
43.	STOLICZKA, DR. F.—Mem. Geol. Sur., India, Vol. V, pt. 1 .	1865
44.	VERNEUIL, M. DE—Note to Dr. Verchere's paper. Jl. A. S. B., Vol. XXXVI	1867
45.	WAAGEN, DR. W.—Carboniferous ammonites. Mem. Geol. Sur., India, Vol. IX, p. 351	1872

ERRATA.

Page 23, line 19 from bottom, *for* " Gastropeda" *read* " Gastropoda."
" 23, line 5 from bottom, *for* " *Lepida*," *read* " *lepida*."
" 23, line 2 from bottom, *for* " *Lamellibranciata*," *read* " *Lamellibranchiata*."
" 24, line 8 from top, *for* " *latelarıs*," *read* " *lateralis*."
" 32, line 18 from top, *for* " J. Wiener" *read* " Tschermak."
" 32, line 19, and again on page 80, *for* " *Jahrbuch der k. k. Geologischen Reichsanstalt*, XXIII, No. 2," *read* " *Mineralogische Mittheilungen*, 1873."
" 40, line 13, *for* " 1921" *read* " 1221."
" 47, line 14 from bottom, *for* " Wycher" *read* " Wychler."
" 51, line 10 from top, *for* " Augustan" *read* " Angustan."
" 54, in-cut margin, line 3, *for* " Karangu," *read* " Karangli."
" 55, line 11 from bottom, *for* " Badrée," *read* " Badra."
" 70, line 17, *insert* " No. 1" before " *Red Marl: Gypsum: Rock-salt*."
" 70, margin, after salt marl, *dele* " No. 1."
" 72, line 3 from bottom, *for* " 200" *read* " 2,000."
" 84, line 10 from top, *for* " dessication" *read* " desiccation."
Pages 98, 99. Names of formations in Italics should be in Romans.
Page 108, line 4, *dele* " No. 15."
" 227, Plate XXIII, fig. 43, *for* " ban" *read* " band."
" 238, margin, *for* " inside" *read* " in side."
" 252, in-cut margin, line 1, *for* " carboniferous" *read* " carbonaceous."

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

ON THE GEOLOGY OF THE SALT RANGE IN THE PUNJÁB, *by* A. B. WYNNE, F.G.S., *Geological Survey of India.*

CHAPTER I.

INTRODUCTORY.

The range. Its important character.

THE Salt Range has long been known as one of the most interesting and important regions in British India, its geological interest being enhanced by its highly fossiliferous rocks, and its importance chiefly derived from the enormous deposits of rock-salt which it contains.

Early acquaintance with its importance.

Its mineral wealth,* doubtless, early prompted the acquisition of information concerning it, and years before the conquest of the Punjáb by the British Government, while the eventful campaign in Afghánistán was taking place, British officers penetrated the wild countries then upon our frontier, not always without risk of life and armed hostility; and returned to report, amongst other things, upon the geology of the district under notice.

* The Government receipts from the Cis-Indus Salt Mines for the years 1867 to 1871 (excluding Kálábágh) exceeded £1,474,549 (Rept., Inland Customs, official year 1870-71, p. 14). "The average yearly revenue from the whole department of the Salt Range for the last five years was £382,658" (MS. letter from H. Wright, Esq., Collector, Shahpúr, July 29, 1872). The rate at which the salt is sold is Rs. 3-1 per maund, or 6s. 1½d. (at par) for 123 lbs.

Since then much has been learned on this subject; but it was not till a few years since that circumstances enabled detailed examination to be made by the Geological Survey. The examination of the rocks was supplemented by an investigation of the fossil-bearing strata in the field by Dr. W. Waagen.

Geological examination.

In carrying on the examination of the ground, I had the advantage of using one of the best published maps of any part of India—one, indeed, rivalling those produced by Government in Great Britain—that of the Jhelum, Sháhpúr, and Leia tracts, constructed by Captain D. G. Robinson, R.E., with his assistants, and published on the scale of one inch to a mile. This scale is sufficiently large to permit an effective representation of the salient features of the ground; but the value of the map in this respect is somewhat impaired by the quantity and manner of the hill shading, which frequently exaggerates the depth of the smaller stream valleys. Yet the features are often so faithfully delineated that the stratigraphical structure of the ground (or consequences depending thereon) can be discerned by the "ornament" upon the sheets.

Map used.

Geographically, the Salt Range* is situated in historic ground, one extremity resting upon the ancient Hydaspes or Jhelum river, the other on the Indus or Aba-sin (Father of waters), and its eastern extension overlooks the battle-field of Chilianwala,† marked by a memorial obelisk built of materials taken from the range. It extends from near 71° 30′ east longitude to beyond 73° 30′, and the Cis-Indus portion of it lies wholly between the parallels of 32° 23′ and 33° of north latitude, forming part of the *Kohistán* or upland of the "Sind-Saugor Doab."

Geographical position.

Its connection with the outer Himalayan hills is completely broken through by the Jhelum valley, and its eastern portion is divided into three nearly parallel spurs

Relation with the outer Himalaya.

* Or "Jood mountains." Burnes, Jour. As. Soc. Bengal, Vol. I.

† Fought January 13th, 1849.

—the Bakrála or Diljaba ridge, that of which Mount Jogí Tilla forms the summit, and the Pubbí or Khárián hills south of the Jhelum. The latter, indeed, hardly belong to the Salt Range proper, being separated from it by the valley of this river, but form a small independent anticlinal chain aligning itself more with the Salt Range than the outer Himalaya.

Situation, length, &c.

The Salt Range proper lies entirely Cis-Indus, forming a somewhat elevated border to the Rawal Pindi plateau (lying to the north), and throughout its whole length of about 152 miles presents its steep declivities and lofty escarpment cliffs towards the vast plains and deserts which spread from its foot through Sind to the sea near Kurrachee.

Not continuous with Trans-Indus salt-field.

It appears to have been the fashion to speak of the Salt Range of the Punjáb as extending across the Indus through the Trans-Indus salt region and up to the Sufég Koh in Afghánistán—an error adopted from some of the earliest writers on the neighbouring countries. Both geographically and geologically, the continuation of the Salt Range westward manifestly lies to the south of the Trans-Indus salt region, the salt of which is believed to be of entirely different age and position from that of the Salt Range proper.*

Previous Observers' publications, &c.

Contributions to the geological literature of the Salt Range have been so numerous in various forms, chiefly as reports to Government or papers to societies, and some of these have been so copious, that extended notice of each would exceed the space which can be fairly devoted to them here.†

The past sixty-one years have witnessed the appearance of about forty-two papers or records concerning this subject, and others may have escaped observation. To those to which access could be obtained notice

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* See Memoir on the Trans-Indus Salt Region, Memoirs Geological Survey, India, Vol. XI, pt. 2, P. 32.

† See list of references appended to preface.

is due, however meagre, because the accuracy of some contrasts very favourably with the generality of early writings upon Indian Geology, while the views put forward in many others cannot be considered established.

In briefly alluding to these writings, parts having special reference to the geology of the Salt Range or connection with it will demand attention.

The earliest publication in which I have found any mention of "the Salt Range" is "Elphinstone's Caubul."* He speaks of a branch of the Sufèd Koh, "which may be called the Salt Range," as shooting out from the Sufèd Koh and extending in a south-easterly direction by the south of "Teeree" to "Callabaugh" (Kálábágh), where it crosses the Indus, stretches across part of the Punjáb and ends at "Jellaulpoor," on the right bank of the Hydaspes, becoming lower as it gets further from the mountains of "Salimaun." He says it abounds in salt, which is dug out in various forms at different places.

Elphinstone, 1808—1815.

In the days when Elphinstone travelled as a British Envoy to the Court of Caubul (Kábul), the whole of the Punjáb and Kashmír were included in the Afghán dominions, and the country was so little known that it can be understood how he might have been mistaken as to the continuity of this range. It would appear from the quotation above that the Salt Range owes its present name to this traveller.

The author describes "Callabaugh† or Karrabaugh," *i. e.*, Kálábágh, with its narrow road cut through solid salt rock, hard, clear, and almost pure, but in some parts tinged and streaked with red—a colour prevailing

* Account of the Kingdom of Caubul and its Dependencies, by the Hon'ble Mountstuart Elphinstone, p. 108. London, 1815.

† The author, adopting the method of spelling the names of places with appropriate English letters, had some slight difficulty to contend with; yet any one familiar with the native pronunciation of several of the names he uses will observe how faithfully, as he writes them, they convey the sounds which these words have in Upper India, or at least the Upper Punjáb.

in the soil of the place. Salt in large blocks like quarried stones was lying (as it does often still) piled at the entrance of the Lún Nala,* ready for exportation to India or "Khorassaun."

Another early record appears as an abstract of Lieutenant Burnes' (afterwards Sir A. Burnes') paper on the geology of the banks of the Indus, &c † He describes the salt as being found in "layers of about a foot in thickness, separated from each other by thin strata of clay," referring no doubt to the laminated structure of the salt, and perhaps mistaking the darker coloured lines for earthy layers. He found what he supposed to be bituminous coal at Kohát, and stated that the Salt Range "extended across the Indus into that district," supporting an often-repeated error. The abstract seems much condensed, and but little is said of the Salt Range proper.

Lieutenant A. Burnes, 1831-32—1838.

In another paper by the same author‡ the locality of the range as the southern limit of a plateau between the river Indus and the Hydaspes is correctly given, as is also the general elevation, but this is followed by a statement that the formation is "sandstone occurring in vertical strata." The desolate aspect of the hills, the hot springs, alum, galena, and sulphur, are mentioned, as well as a red clay in the valleys, indicating salt, which is found at intervals throughout the range.

Lieutenant A. Burnes, 1832.

A description of the "Keoru" (Kheura) mines follows. Gunpowder was not used lest the roof should fall in, accidents of the kind occurring even then. The miners received a rupee for 20 maunds of salt raised, and its selling price was Rs. 2 per maund exclusive of duties. The profit is stated to amount to about 1,100 per cent., and from it Runjit Singh hoped to derive a revenue of 16 lakhs of rupees. The mode of

* Called by Jameson the Gossai Nala.

† A Memoir on the Geology of the banks of the Indus, the Indian Caucasus, and the plains of Tartary to the shores of the Caspian, by Lieutenant A. Burnes, Proc. Geological Society, London, Vol. II, p. 8.

‡ "Some account of the Salt Mines of the Punjáb," by Lieutenant S. [A.] Burnes, Bombay Army, Journal of the Asiatic Society, Bengal, Vol. I, p. 143, &c.

extraction was by sledge-hammer and pickaxe, and from near the surface blocks of 4 maunds each were raised. The salt is said to have held a high place throughout India with native practitioners on account of its medicinal virtues, but it is stated to have been impure, having a considerable mixture, probably of magnesia, which rendered it unfit for curing meat. The Punjábis ascribed to its effects the prevalence of *nazla*, a disease said to consist of a running at the nostrils.

In those days the salt was not exported west of the Indus. The antiquity of the mines was unknown, and they are said not to have been mentioned by the inquiring Baber in his Commentaries, though they had been used by the Emperors of Hindústán.

Agha Abbas of Shiraz, 1837.

In the course of a tour through the Upper Panjáb and Afghánistán made by one Agha Abbas (at the suggestion of Major R. Leech, by whom the story of his travels was translated*), this person mentions having seen 500,000 maunds of salt covered with mud, as a protection from the rain, at Pind-Dadun-Khan. Several of the mines were then closed, including those at "Sardee" (Sardí), "Neelawan" (Nílawan), "Durnálá," and "Chotana" (Jútáná), and the latter was said to contain veins of copper and lead. Others, as at "Korah" (Kheura) and Makraj, were open. From his description these mines appear to have been very irregularly worked, lighted by openings at top, and dangerous from falls of the roof, one of which he witnessed. Blocks were cut by digging round two sides and below with picks, then detaching from above by heavy blows. The mines of Nílawan and Khur Chotata were the finest.

The cost of carriage from the mines to Pind-Dadun-Khan was one rupee for 20 maunds of salt, and the selling rate, by the Government of Maharaja Golab Sing, was to some merchants one and a half, to others two rupees. Formerly, the mines produced four lakhs of rupees; after the visit of Captain Wade† they yielded from eight to nine, afterwards

* Journal of the Asiatic Society, Bengal, Vol. XII, p. 564. 1843.

† Afterwards Sir Claude Martine Wade, Vigne's Kabul, p. 2.

from twelve to fourteen lakhs, then fourteen lakhs, at which figure Agha Abbas found the revenue in the time of Golab Sing, though twenty-five lakhs were said to be realised. The labourers were paid one, two, or three annas a day, and then, as now, the miners and their families all worked in the mines. The mines were farmed by Maharaja Runjeet Sing to Golab Sing.

In another part of the narrative twelve saltpetre (*sic*) factories are mentioned at Karabagh (Kálábágh), producing a revenue of Rs. 12,000, the tourist evidently alluding to the alum works. Throughout the paper, passing notice is taken of the salt and other mines of the country; but the quantity of mineral wealth appears to have been exaggerated.

Munshi Mohun Lal, January 1838.

When Mohun Lal visited Kálábágh or Bághan* there were ten alum factories there, and two hundred at Moch on the other side of the river (probably one of the localities in the Amb valley beneath Sakesir?). The manufacturing process is very roughly described, and the selling price stated at Rs. 2 per 8 maunds.

Twenty-one salt mines were then worked on the other side of a neighbouring mountain (along the Lun Nala probably), the 'crop' of the salt being described as like a line of shining marble across and through the mountain, at the base of which the numerous holes in the salt were attributed to the grazing of cattle! He says that Rs. 3,00,000 worth of salt per annum used to be raised here. He alludes to sulphur mines, of the situation of which the Sikh authorities were not aware, though they were known and used by the Malik of Kálábágh.

Dr. Jameson, November 1841.

Writing from Kálábágh, under date 15th November 1841,† Dr. Jameson asserts himself to be in the "saliferous system," which "extends uninterruptedly from that place to Jubbulpore."

* Account of Kálábágh on the right bank of the Indus: Journal of the Asiatic Society, Bengal, Vol. VII, p. 25.

† Extract from a letter to Mr. Clerk, Journal of the Asiatic Society, Bengal, Vol. XI, p. 1.

Of the coal of Kálábágh he says that 2,000 maunds had been collected, for which the people (valuing it from its supposed medicinal qualities) demanded Rs. 4 per pucka maund. He thought no good fuel would be discovered there, basing his opinion upon the idea that valuable coal only occurred in the carboniferous formation, and apparently unaware that there were rocks of that period within a few miles. He grouped the coal and sulphur-bearing beds [alum shales] of Kálábágh with the salt marl. Among the riches of the country he enumerates gold, iron, sulphur, salt, gypsum, limestone, and saltpetre. The gold was of course the small quantity of that metal obtained by stream-washing from the Indus at Kálábágh; the sources of the iron and saltpetre are not given.

Dr Jameson, 1843.

In 1843, Dr. Jameson's "*Report* of his deputation by Government to examine the effects of the great inundation of the Indus*" was published. He experienced much difficulty in consequence of the loss of almost all his notes, his baggage, collections, &c., when attacked and driven back by the Afrídís, at the Kotul Pass, followed by his confinement in the Fort of Kohát. He speaks of the lowest stratum in the range at several places as being of magnesian limestone. He perhaps alludes to some thin flaggy dolomitic layers in the red salt marl, but these cannot be said to occupy the position attributed to them.

His rock descriptions are not always sufficiently clear for recognition. He asserts that the Salt Range is parallel to the central or high mountain range of the Himalaya †

The alum slate of Kálábágh is said to alternate with the red marl. The manufacture of alum from the slate by lixiviation, &c., is described, and the produce is stated to have fetched Rs. 19-4 per 6

* Journal of the Asiatic Society, Bengal, 1843, Vol XII, p 183, &c.

† Elphinstone, previously mentioned, seems to have written before this word was corrupted into the present form as above, he spells it "Hemalleh," which closely approximates to the way natives of Upper India pronounce it.

maunds=384 lbs., of which Rs. 2-4 were exacted as duty by the Malik, whose income of Rs. 10,000 per annum was entirely derived from the mineral resources of the country: the salt trade, however, being, with the exception of 300 to 700 maunds, which the Malik was permitted to sell, monopolised by Rajah Golab Sing.

Dr. Karsten, 1846.

In his bulky *Lehrbuch der Salinenkunde*, published at Berlin in 1846, Vol. I, page 677, Dr. Karsten refers to the Salt Range and Trans-Indus Salt rocks speaking of both as belonging to one continuous range springing from the Sufėd Koh of Afghánistán, thus repeating the error of previous writers, from whom he appears to have derived it.

Dr. Andrew Fleming, 1848—1853.

Next in order of time are the first of the more extensive and accurate writings of Dr. A. Fleming, who with two assistants was specially sent by Government to make a survey of the geology of the Salt Range.*

The ability and general accuracy of description with which Dr. Fleming's reports are fraught, contrast with many of the geological writings of early Indian observers. His examination of the district in question was both more careful and more detailed than that of his predecessor, and was attended with much sounder results.

His first report, 1848.

The first of his papers mainly refers to the minerals and their sources, his preliminary examination having been cursory and his determination of the geological horizons of certain of the strata affected by the effort to correlate distant deposits closely with the European series.

His diary, 1849.

His second paper † is an interesting diary of the journey on which he appears to have collected the data of his first report.

* Report on the Salt Range and on its coal and other minerals, by Andrew Fleming, M.D., Edinburgh, Assistant Surgeon, 7th Bengal Native Infantry: Jour. As. Soc., Ben., Vol. XVII, p. 500. 1848.

† Diary of a trip to Pind-Dadun-Khan and the Salt Range, by the same author: Jour. As. Soc., Beng., Vol. XVIII, p. 661. 1849.

In a letter to Sir R. I. Murchison,* Major Vicary details numerous cursory observations upon the geology of the Upper Punjáb, made while campaigning in the country, his military movements being too rapid to permit of closer observation. His route may be traced, but roughly, by the villages and passes, &c., which he names; he thus seems to have crossed the extreme easterly portion of the district under notice, and "had reason to think the red shales and clays, sandstone, and conglomerate beds beneath"—to which he applied the term eocene—were "the same formation so productive of salt near Pind-Dadun-Khan;" indeed, he extends the observation, and from the accounts of Dr. Fleming and Dr. H. Falconer, concludes that the red shales near Subáthu, Nahu (Náhun), and Mandí were all on the same horizon as the salt-bearing zone of the Salt Range.

Major Vicary, December 1850.

Major Vicary separated the tertiary rocks through which he chiefly marched, into eocene red beds, bone-bearing Sewalik, and an extensive deep-bedded pliocene group.

Captain Strachey, in his Himalayan paper,† makes but slight reference to the Salt Range: he describes a persistent belt of (Sewalik) tertiary strata supposed to belong to the miocene period as extending along the whole flank of the Himalaya from the Sutlej to the meridian of Calcutta, with an intervening zone between it and the mountains, "chiefly consisting of light-coloured sandstones often containing small seams of lignite and imperfect vegetable impressions, often associated with marls and gypsum, and sometimes with salt springs." These he supposes, from their abnormal dip towards the mountains, to have been brought into position by a series of great faults at the foot of the range. He mentions that they are surmised, from their mineral character, to be of the saliferous age, and that

Captain Strachey, 1851.

* On the Geology of the Upper Punjáb and Peshawur: Proceedings, Geol. Soc., London, Vol. VII, p. 39, &c.

† On the Geology of part of the Himalaya Mountains and Tibet, by Capt. Richard Strachey, Bengal Engineers, F.G.S., Proc., Geol. Soc., London, Vol. VII, p. 292, &c., June 1851.

they are possibly the extension of the strata containing rock-salt found on the same general line to the west in the Punjáb.

Next comes the most valuable of Dr. Fleming's reports, that accompanied by a map and sections.* In conducting his survey, Dr. Fleming had the advantage of the assistance of Mr. William Purdon, the memory of whose engineering improvements still lasts in the Salt Range, and also that of Mr. William Theobald, now one of the senior officers of the Geological Survey of India. Considering the short space of time allowed for the completion of the examination, the report may be fairly called exhaustive. Errors as to the positions assigned to certain groups in his former report are corrected, the physical features and botany described, and full details of the geological structure and development of additional groups in the western part of the range are given.

Dr. Fleming's second report, 1858.

The mode of mining the salt, manufacture of alum, washing of gold, and sublimation of sulphur, are described at length, and the position and character of the coal deposits and petroleum springs are noticed. Analyses of some of the rocks are inserted; and the organic remains, together with the minerals, receive attention in the description of each of the principal groups in which the rocks are classified.

In a passage upon the upheaval of the range, Dr. Fleming makes deductions as to the various depths at which the strata were deposited and other physical conditions, arguing from the conformity of the whole that they had all been elevated subsequently to the deposition of the newer tertiary beds. The upheaving force he thought extended from the east to the west, perhaps progressively, but this is not plainly stated; and though he looked upon Mount Tilla as shewing an anticlinal structure, he favours the idea of the elevation having taken place along a line of fracture further westwards and having affected a greater area. Beyond

* Report on the geological structure and mineral wealth of the Salt Range in the Punjáb, with maps, sections, &c., by the same author, in charge of the Geological Survey of the Salt Range in the Punjáb, season 1851-52: Jour. As. Soc., Bengal, 1853, p. 230, &c.

(west of) Sakesir he observed an anticlinal structure again, and he thought the elevation of the Himalayas coeval with that of the Salt Range, "this fact fully explaining the anomalous dip along their southern side of the newer formations under the metamorphic schists of the central ridge as observed by Captain Strachey."

On reading this report, it becomes evident that the impossibility of reconciling the series of the Salt Range with those of Europe on the basis of its saline and coal-bearing groups being equivalent to the trias and carboniferous had struck Dr. Fleming, but he still adhered to the idea of more or less close correlation, and, apparently commencing from the carboniferous limestone, referred the groups above to the tertiary and oolitic periods and below to the Devonian, in the latter of which he placed the salt and its associated rocks.

The most important geological discovery made by Dr. Fleming was, perhaps, that of the existence of carboniferous strata in the western part of the range, when returning from his first visit in 1848. Amongst the fossils which he then found, he names *Productus*, *Terebratula*, *Spirifer*, *Ammonites*, and *Belemnites*. These were sent to Europe for identification, and, through the intervention of the late Sir R. I. Murchison, examined by M. de Verneuil, who determined "five out of eight or nine species" to be "forms well known in the rocks of carboniferous age." The *Ammonites* and *Belemnites* are alluded to with doubt in the larger report, at page 260, as "*what we took for*" these fossils; but although *Ceratites* are subsequently mentioned as having been found, the author asserts that these belonged to the carboniferous limestone, on the strength of their occurrence with *Orthoceratites*.

It would appear that the salt was supposed by Dr. Fleming to consist of a single bed, and he alludes to a singularly eruptive appearance of the accompanying marl, though its stratification at the west side of the range "negatives the idea." He thinks it probable, however, that "it has undergone metamorphism from igneous influence," notwithstanding the absence of "plutonic or volcanic rocks by which this might have been

caused." In connection with this subject, a singular chocolate-coloured argillaceous rock is mentioned as of somewhat "trappean" aspect, occurring where the junction of the marl and overlying purple sandstones takes place, and supposed to be a "metamorphic argillaceous sandstone."

The greater number of the mines he thought confined "to detached masses of salt, sometimes with horizontal or vertical lines of stratification, depending on their position at the time they became fixed in the consolidating gypseous paste."

At the time of his report,—in the years 1850 and 1851 respectively,—768,603 and 640,618 maunds of salt were extracted, yielding a revenue of Rs. 15,37,400 in 1850 and Rs. 12,81,295 in 1851, at a selling rate of Rs. 2 per maund of 40 seers.*

Geological notices of Kálábágh, Musakhel, Kaffir Kote, Banu, the Korána hills, and Murree, will also be found in the report.†

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* *l. c.*, p. 248.

† For the sake of comparison with other or the most recent classifications of the rocks, that of Dr. Fleming is appended. He recognised the following formations, which are arranged in his table in reverse order, but are here placed naturally, the oldest lowest:—

4. POST TERTIARY	RECENT	...	Alluvium.
3. TERTIARY ...	MIOCENE ?	...	Greenish sandstones, argillaceous grits, conglomerates, and red and green clays.
	EOCENE	...	Brown calcareous sandstone, nummulitic limestone, marls and alum shales with lignite.
2. SECONDARY ...	OOLITIC	...	*c.* Green Belemnite sandstone and shales.
			b. Cherty thin-bedded limestones with shales.
			a. Yellow iron-stained quartzose sandstones, grits, and bituminous shales.
1. PRIMARY OR PALÆOZOIC	CARBONIFEROUS...		*c.* Upper limestone, sometimes magnesian.
			b. Grey sandstone and shales.
			a. Lower limestone, calcareous sandstone, and shales.
	DEVONIAN	...	*d.* Upper red variegated sandstone, grits, conglomerates and clays.
			c. Greenish micaceous sandstones and shales with grey dolomitic (magnesian) sandstone.
			b. Lower red sandstone and grit with conglomerate.
			a. Red marl with gypsum and rock-salt.

The reference to the Korána hills* is, so far as I am aware, the only information extant about their geological structure, except the mention made of them by Mr. Theobald in a paper to be noticed presently. Dr. Fleming could not recognise among their dark-coloured and quartz-veined beds of coarse, brown, ferruginous sandstone, greenish quartzite and silicious clay slate, any representatives of the Salt Range series, but considered them rather as lower Silurian or Cambrian, and subordinate to the salt formation of the range. No fossils could be detected, but filling small cracks in the sandstone small specimens of pyrolusite or peroxide of manganese were found, and numerous white quartz veins contained masses of rich hæmatitic iron ore.† The beds dip to the north-west at angles of 40° to 45°.

These hills are situated in the Jetch Doab near the River Chenab (or "*Ascesines*," Elphinstone's Caubul, page 24) and 24 miles south-eastward of Sháhpúr. They rise by Dr. Fleming's measurement about 957 feet above the plains of the "Bár."

On the whole, this report is highly interesting and abounds with information.

Dr. Fleming and Sir Roderick I. Murchison, 1853.

A paper by the late distinguished geologist, Sir Roderick I. Murchison, with abstracts of letters from Dr. Fleming and his own remarks thereon, appeared in the Quarterly Journal of the Geological Society, London, for August 1853,‡ accompanied by a sketch map.

Dr. Fleming's letters herein alluded to are dated in 1851-52, and express opinions which he altered during his correspondence with Sir Roderick, from whom he learned that salt occurred in all formations

* *l. c.*, p. 444.

† Limonite, composed of peroxide of iron, silica, and water,—*vide* paper by Dr. Fleming, Jour. As. Soc. Beng., XXIII, p. 92. 1854.

‡ On the Salt Range of the Punjáb, by A. Fleming, E.I.C., Assistant Surgeon, 4th Punjáb Cavalry (Abstract of letters addressed to Sir R. I. Murchison): Quarterly Journal of the Geological Society, London, Vol. IX, p. 189. 1853.

from the oldest to the youngest, and that the salt of Livonia (Russia) occupied the same position as that of the Punjáb.

Among the fossils Dr. Fleming had sent home, Messrs. de Verneuil and Davidson had recognised—

Productus cora,
P. costatus,
P. Flemingi,
Orthis crenistria?
Terebratula Roysii,
T. crispata?

and new species of *Terebratula.*

Sir R. I. Murchison.

Sir Roderick observed that the second letter of Dr. Fleming's was chiefly remarkable for the author's belief, drawn from physical phenomena, that the chief saliferous masses had been produced by eruptive agencies. This opinion was purely the result of observation, as Dr. Fleming was unaware some distinguished geologists have held the same views.

D'Archiac and Haime, 1853.

In the valuable work of Vicomte D'Archiac and M. Jules Haime,* the geology of the Salt Range is referred to. They give in their geological *résumé* (page 172, &c.) a sectional representation of the range, which may be considered diagramatic, for it includes together groups seen only at its opposite ends, and represents a strong unconformity between the tertiary sandstones and the underlying limestone which has not been found to exist. Taking their information perhaps from the observations of Dr. Fleming, the authors described the lowest rocks as Devonian, including conglomerate (1), gypseous and salt-bearing rocks (2), and red sandstone (3). Above these are slaty and calcareous clay and sandstones (4 and 5), supposed to represent the carboniferous formation, then limestone

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* Description des Animaux Fossiles, du groupe Nummulitique de l'Inde, par le Vicomte D'Archiac et Jules Haime. Paris, 1853.

and carbonaceous slates (6), jurassic, succeeded by (7) nodular sandstone, and shaley bituminous clay with lignite and limestone with *Nummulites* (8), shaley grey limestone with *Nummulites* (9), grey or yellowish limestone marly or sandy and sub-compact, and (10) nodular sandstone, the whole from No. 7 forming the lower tertiary sub-division, overlaid by (11) younger tertiary rocks with bones.

In their palæontological *résumé*, the authors refer to the Punjáb as their "second region" or province, the first being Sind, Beluchistan, and Kach, and the third the Himalayan or Subáthu division. Of the forty-four Punjáb (Salt Range) nummulitic species of fossils, they found eighteen common to the first province, but none common to the Salt Range and Subáthu rocks. They appear not to have known any Salt Range *Cephalopoda*, and of its *Echinodermata* mention only one species.

Mr. Theobald, 1854.

The next account of the geology of the Salt Range is by Mr. Theobald,* who had, when exploring the range with Dr. Fleming, good opportunities for studying the subject. The paper was written three years before it was published, but revised and curtailed owing to the publication of others on the same subject in England. The writer gives a close description of the physical features and general appearance of the range, its direction, length, and width, remarkable points and heights.

Passing to the geology of the range, Mr. Theobald avoids discussing the identity of the geological groups with similar ones in Europe, but remarks that "it would not be difficult to identify almost every bed of the permian and saliferous rocks of Europe by lithological character with the beds of the Salt Range below the nummulitic limestone, but in an inversed order." He contends that as the whole of the strata are conformable they were deposited during subsidence, and he attributes the formation of valleys on the plateau and gorges leading thence to the

* *Notes on the Geology of the Panjáb Salt Range, by* W. THEOBALD, *junr., Assistant, Geological Survey of India, late of the Punjáb Geological Survey:* Journal of the Asiatic Society of Bengal, Vol. XXIII, p. 651. 1854.

south to forces no longer existing, but resembling those by which the Falls of Niagara were excavated.

The different groups with their thicknesses are represented in a list (extracted below*), and tolerably full descriptive observations upon each group follow, an extract from a former report being given regarding the Bághanwálla coal, and a section to explain the position of the petroleum springs at Jábbi.† The suddenness with which fossils appear in the lower (or *Productus*) limestone group is adverted to, none being found below. The Korána hills referred to by Dr. Fleming are also noticed,‡ and the rock of the Kheura gorge, &c., alluded to by the latter as of "somewhat trappean aspect," is declared to be an actual trap. Appended to the paper is a list of tertiary Mammalian and other fossil remains identified

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* Mr. Theobald's list is given in inverted order, but here restored, for sake of uniformity, to the natural one.

	Feet.
10. Nummulitic limestone, conglomerate, green, red, and yellow ossiferous sands, marls and conglomerates, minimum .	10,000
9. Upper or nummulitic limestone .	1,100
8. Carbonaceous shales, sandstone, and lignite	80
7. Red and green, white spotted shales and sandstones ..	600
6. Lower (or *Productus*) limestone	1,100
5. Hard fawn-coloured sandstone with bands of conglomerate ..	700
4. Cupriferous purple shale, and red friable grits and conglomerates	400
3. Dark arenaceous shales with green earth	250
2. Dark-red sandstone, fine grained with black iron sand partings...	700
1. Red marl and gypsum with rock-salt	1,500
TOTAL ...	16,430

† Jaba on the Government maps.

‡ As formed of a species of slate with feebly developed slaty structure and deep ripple marks, gray, stained red and yellowish, and weathered to a dark burnished brown, with intensely ferruginous burnt aspect, white quartz veins, much peroxide of iron, and a curious carbonate of lime and iron (Jour. As. Soc., Beng., Vol. XXII, p. 206), having 65·14 per cent. of carb. lime, which formed half a one-foot quartz vein.—*Jour. As. Soc., Beng., Vol. XXXII, p. 674.*

by the late Dr. Falconer as being, with a single exception, entirely of the character of those of the Siwalik hills.*

Some of the sub-divisions are differently placed by Messrs. Fleming and Theobald. "The fawn-coloured sandstone," No. 5 of the latter, is placed above Dr. Fleming's Devonian "d," instead of being included in a lower division "c"; Mr. Theobald's No. 7, a zone marked by the

* As this list may prove useful for reference, it is given below. The fossils were from near Jelalpúr and Lehri (the latter eastward of the Bakrála ridge), and the absence of *Carnivora* is noticed.

PACHYDERMATA.

PROBOSCIDIA.

Elephas.—A plate of a worn molar, species undeterminable, but probably E. Hyendricus.

Mastodon.—Two specimens of molar ridges of the Elephantoid or *Stegodon* group, species undeterminable.

Two fragments of ivory tusks.

Hippopotamidæ.—Tusks of the lower jaw of a larger size than are usually met with in the Siwálik *Hexaprotodon*, and resembling more the true Hippopotamus or *Tetraprodon* of the Nerbudda.

Rhinoceros.—Upper and lower molars in fragments.

Equus.—Upper and lower molars of two species.

Sus.—Upper jaw.

RUMINANTIA.

Sivatherium.—Lower jaw (fragment) with tooth.

Bos.—Upper and lower molars and fragments of jaws.

Cervus and *Antilope.*—Several species, some of them very minute, abundance of astralagi, femur ends, and scapula caps, also fragments of deer's horns.

Camelus.—Portions of a molar.

AVES.

Fragment of a leg bone, with the articular surface, of a large form, belonging to the Grall .

REPTILIA.

Crocodilus and *Leptorhynchus* (*Gavialis*).—Lower jaws and teeth with vertebræ.

Trionyx.—Fragment of the carapace with vertebræ of a large species.

Fish.—A vertebra.

MOLLUSCA.

A few lime casts of one of the species found in the Siwálik hills.

H. F.

Calcutta, 12th September 1854.

prevalence of pseudomorphic salt crystal casts, and by him placed high up in the series, is the upper member of Dr. Fleming's Devonian according to the sections given by the latter.

Sufficient has been said to shew the important character of the paper, the general conclusions arrived at approximating more or less to those of Dr. Fleming previously noticed.

H. B. Medlicott, 1859.

During a visit to the Punjáb in the winter of 1859-60, Mr. Medlicott had an opportunity of seeing the relations of the rocks at the eastern end of the Salt Range, and some of them are alluded to in his memoir upon the southern Himalaya between the Ganges and Rávi.*

He observed a difference between the grouping of the Subáthu series and that of the Salt Range nummulitic limestone and next succeeding beds, certain hard sandstones and red clays of Subáthu not being present in the Salt Range where the massive unconsolidated mammaliferous clays and sands of the upper Sub-Himalayan (Siwálik) group are stated to rest upon a denuded surface of the nummulitic limestone. The great difference between the fossils of the two localities as enumerated by D'Archiac and Haime is also alluded to; out of forty-four species from each, none are common to both, and those of Subáthu are of shallow water forms as compared with those of the Salt Range.

In describing the salt mines of Mandí and Drang, Mr. Medlicott notices the presumption by previous geological observers that the salt rocks of Mandí are beyond question the geological equivalents of those of the Panjáb (Salt Range, &c.). The position of the Mandí salt being, however, fixed by Mr. Medlicott as well within the general boundary of his Krol group,† and not in the Sub-Himalayan rocks, the clue which the latter

* Memoirs of the Geological Survey of India, Vol. III, Pt. 2, "Subáthu group." Abstract on same subject.—*Jour. As. Soc., Beng., Vol. XXX, p.* 22. 1861.

† Since Mr. Medlicott's memoir was written, the "Krol" rocks have been supposed of triassic age, and the Mandí salt has been recently thought by Mr. Theobald (MS. communication) probably of eocene age.

might have afforded to the age of that salt is lost, and only the total dissimilarity of the associated rocks in each region indicate these saline deposits of Mandí to be different from those of the Salt Range.

For the sake of comparison, Mr. Medlicott's district being the nearest carefully examined ground in that direction to the Salt Range, his classification of its rocks is abstracted from the memoir and given below.*

Thos. Davidson, 1862.

A paper in the Quarterly Journal of the Geological Society of London for February 1862,† by the distinguished palæontologist, Mr. Davidson, treats of the carboniferous *Brachiopoda* of the Salt Range collected by Fleming and Purdon. Seventeen species are described, including the Genera *Terebratula, Athyris Retzia, Spirifera, Rhynchonella, Streptorhynchus, Orthis, Productus, Strophalosia*, and *Aulosteges*. Several of these are figured, and the author observes that the total number of carboniferous *Brachiopoda* thus discovered "amounts to about twenty-eight species, of which thirteen at

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* *Sub-Himalayan Series.*

UPPER ...	Siwálik	Conglomerates, sandstones, clays.
MIDDLE ...	Nahun	Lignite sandstones and clays.
LOWER	Subáthu [since "Sirmur"]	Kasaulí, gray and purple sandstones.
		Dagshai, purple sandstones and red clays.
		Sabáthu, fine silty clays with limestone. (*Nummulites.*)

Himalayan Series.

1.—UNMETAMORPHIC—

KROL ...	Krol Hill ...	Limestones.
INFRA KROL	Ditto ...	Carbonaceous slates or shales.
BLINI ...	Blini River ...	Limestone and conglomerate.

2.—METAMORPHIC—

Crystalline and sub-crystalline rocks, &c.

† On some carboniferous Brachiopoda collected in India by A. Fleming, M.D., and W. Purdon, Esq., F.G.S., by T. Davidson, Esq., F.R.S., F.G.S. Quar. Jour. Geol. Soc., London, Vol. XVIII, page 25, Feb. 1862.

In a foot note to the paper, Mr. Davidson mentions the following species as having been identified by M. de Verneuil and himself in 1858: *Athyris Roysii*, a *Spirifera* nearly related to *S. lineata, Streptorhynchus crenistria, Productus Cora, P. Flemingii, P. costatus*, and *P. Humboldtii*. The determination of some of these first established the fact of carboniferous strata occurring in the Salt Range.

least are common to European rocks of the same period." The geological features of the carboniferous rocks of the district are not dwelt upon further than to mention that the fossils occur in beds differing mineralogically, some being hard and crystalline and others argillaceous, while a few were from magnesian limestone. Dr. Fleming's separation of the carboniferous rocks into three divisions is also given as follows:—

c. Upper Limestone: *Brachiopoda*, and other fossils occur throughout the formation.

b. Gray sandstone and shales, in which but few fossils have been found.

a. Lower limestone, with calcareous sandstone. This limestone generally abounds in large *Brachiopoda* and other fossils.

Some of the species described are said to be identical with specimens from such distant localities as Red River, Louisiana, Iowa, New Mexico, Arkansas, and Bolivia, on the table-land of the Andes.

The following are Mr. Davidson's lists:—

COLLECTED BY DR. FLEMING.

Terebratula (*vel Waldheimia*) *Flemingi*, Dav.
T biplicata Brocchi (?) var. *problematica*, Dav.
T. Himalayensis, Dav.
T. subvesicularis, Dav.
Athyris Roysii, L'Eveillé, sp.
A. subtilita, Hall, sp. var. *grandis*, Dav.
Retzia radialis, Phillips, sp. var.
R. grandicosta, Dav.
Spirifer striata, Martin, sp.
S. Moosakhailensis, Dav.
S. lineata, Martin, sp. var.
Spiriferina octoplicata, Sow., sp.
Rhynchonella pleurodon, Phill. sp.
Camarophoria Purdoni, Dav.

COLLECTED BY W. PURDON, Esq., F.G.S.

Terebratula Himalayensis, Dav.
Athyris Roysii, L'Eveillé.
Athyris subtilita, Hall (?) var.
Spirifera Moosakhailensis, Dav.
S. lineata, Martin, var.
Rhynchonella pleurodon, Phill. var.
Camarophoria Purdoni, Dav.
Streptorhynchus crenistria, Phill.
S. pectiniformis, Dav.
Productus striatus, Fischer.
P. Cora, D'Orb.
P. Purdoni, Dav.
P. costatus, Sow.
P. Humboldtii, D'Orb.
P. semireticulatus, Sow.
Strophalosia Morisiana, King (?) var.

COLLECTED BY DR. FLEMING.

Streptorhynchus crenistria, Phill. sp.
var. *robustus*, Hall.
S. pectiniformis, Dav.
Orthis resupinata, Martin, sp.
Productus striatus, Fischer, sp.
P. longispinus, Sow.
P. Cora, D'Orb.
P. semireticulatus, Sow.
P. costatus, Sow.
P. Purdoni, Dav.
P. Humboldtii, D'Orb.
Strophalosia Morisiana, King (?) var.

COLLECTED BY W. PURDON, Esq., F.G.S.

Aulosteges Dalhousii, Dav.
Crania. (sp. indet.)

The author mentions Dr. Fleming's conviction that all the fossils recorded in his list were derived from rocks of the carboniferous period, and the difficulty he found in referring two of the species of *Terebratula* to this age. They recalled to him certain forms of jurassic or cretaceous age much more than any shells of the carboniferous period with which he was acquainted. He therefore called attention to them with a view to ascertaining whether they might not have been derived from a less ancient formation. That there were good grounds for his doubts will be seen.

Professor de Koninck, 1863.

The Journal of the Geological Society of London also contains a paper by another eminent palæontologist, Professor de Koninck,* upon fossils discovered by Dr. Fleming in the Salt Range. In his opening paragraph, .M de Koninck refers to the paper of Mr. Davidson, mentioning the fact just noticed that some of the *Brachiopoda* do not possess a palæozoic aspect. This feature, he observes, may be remarked likewise among the fossils of other classes in

* Descriptions of some fossils from India discovered by Dr. A. Fleming of Edinburgh, by Dr. L. de Koninck, F.M.G.S., Professor of Chemistry and Geology in the University of Liege. Quar. Jour., Geol. Soc., Lond., Vol. XIX, p. 1. 1863.

This paper, that of Mr. Davidson, the work of D'Archiac and Haime, and the note by M. de Verneuil, are about the only sources of general palæontological information regarding the Salt Range as yet extant, and these refer chiefly to its carboniferous, trias, and nummulitic formations.

Doctor Fleming's collections, and he notices that certain species belong to genera hitherto only found in the secondary formations and principally in the lower groups of that great period. The *Ceratites* in particular are remarkable, all being new to science, and but for this, serious doubts might have been entertained relative to their geological position, though Dr. Fleming had ascertained by personal examination that they occurred in the same beds as those which contained carboniferous *Producti* and *Spiriferæ*. The author remarks, however, that the rock containing the *Ceratites* was without any traces of these other palæozoic genera. The fossils which he had for determination included forty-nine species, five of which were in bad preservation and undeterminable. Those described, thirty-six of which are figured, are as follows :—

I. ANTHOZOARIA.

1. *Isastræa arachnoides*, de Kon.
2. *Clisiophyllum Indicum*, „
3. *Lithostrotion basaltiforme*, Conyb. and Phill.
4. *L. irregulare*, Phill.
5. *Michelinia favosa*, Goldf.
6. *Alveolites septosa* (?), Fleming.

II. ECHINODERMATA.

7. *Philocrinus cometa*, de Kon.
8. *Cidaris Forbesiana*, „

III. MOLLUSCA.

A. Bryozoa.

9. *Polypora fastuosa*, de Kon.
10. *Fenestella megastoma*, „
11. *F.* (?) *Sykesii*, „
12. *Retepora* (?) *Lepida*, „
13. *Phyllopora* (?) *Haimeana*, de Kon.
14. *P. cribellum*, „

B. Lamellibranciata.

15. *Anomia Lawrênciana*, de Kon.
16. *Pecten Flemingianus*, de Kon.
17. *P. Asiaticus*, „
18. *P. crebristria*, „
19. *Solenopsis imbricata*, „

C. Gastropeda.

20. *Dentalium Herculeum*, de Kon.
21. *Bellerophon decipiens*, „
22. *B. orientalis*, „
23. *B. Jonesianus*, „
24. *Macrocheilus depilis*, „
25. *M. avellanoides*, „
26. *Nerinæa* (?) *n. sp.* (?) „

D. Cephalopoda.

27. *Ceratites Flemingianus*, de Kon.
28. *C. Murchisonianus*, „
29. *C. Hauerianus*, „
30. *C. planulatus*, „
31. *C. Lyellianus*, „
32. *C. latifimbriatus*, „
33. *C. Buchianus*, „
34. *C. Davidsonianus*, „
35. *C. Lawrencianus*, „
36. *Goniatites* (?) *Gangeticus*, „

37. *Nautilus Bartini*, Galeotti
38. *N. Flemingianus*, de Kon.
39. *Orthoceras vesiculosum*, „
40. *O. rachidum*, „
41. *O. decrescens*, „

IV. PISCES.

42. *Acrodus, n. sp., closely related to A. latelaris, Ag.*
43. *Acrodus Flemingianus*, de Kon.
44. *Saurichthys* (?) *Indicus*, „

Prof. de Koninck's doubts as to the place of at least some of the *Ceratites* were, it appears, quite as well grounded as Mr. Davidson's regarding certain of the *Brachiopoda*.

Robt. de Schlagintweit, 1864.

In a list of Indian and High Asian hot springs, by M. Robert de Schlagintweit, published by the Asiatic Society of Bengal,* one at Musakhét—a misprint for Musakhél—near the Salt Range is mentioned, coupled with the name of Dr. Fleming, its latitude being 32° 43′ and longitude 71° 39′ at 706 feet above sea-level and its temperature being 94°. This spring is situated in the Bukh Ravine, in the Western Salt Range, between Musakhél and Namal. The water, according to Fleming, gives off sulphuretted hydrogen and deposits sulphur.

Thomas Oldham, LL.D., 1864.

The memorandum† or report in which the former Superintendent of the Geological Survey of India recorded observations, resulting from a visit to this district and its neighbourhood, to inspect the sources of the coal and salt, is chiefly confined to the objects of his journey, time not permitting of detailed geological examination. Dr. Oldham refers to the exploded idea (see Dr. Jameson's report) that useful mineral fuel could only be obtained from rocks of one fixed geological horizon, and demonstrates its fallacy.

Minute details regarding the position, thickness, and circumstances of the coal, as exposed at 19 localities, and in one case a tabular view of part

* Vol. XXXIII, p. 51, &c., 1864.

† Memorandum on the results of a cursory examination of the Salt Range and parts of the districts of *Banu* and *Kohat*, with a special view to the mineral resources of those districts. (Report to Government of India.)

of the section containing it, are given. The prospects of its being remunerative, if worked, are discussed. Some valuable observations and suggestions follow relating to the salt mines and their working system. The Trans-Indus salt mines as well as the petroleum or mineral tar and sulphur of some localities, are also described.

Dr. Stoliczka, 1865.

Dr. Stoliczka, in his paper upon the geological sections across the Himalaya from the Sutlej to the Indus,* makes some reference to the carboniferous fossils of the Salt Range, some of the species being found in his "Kuling beds" or carboniferous series of that Himalayan region. He has also an allusion to the occurrence of newer secondary rocks in the Punjáb which must also refer to the Salt Range.

Dr. A. M. Verchere, 1866-67.

In the voluminous paper on the geology of Kashmir, the Western Himalaya, and the Afghán Mountains,† by Dr. Verchere, are several passages referring to the Salt Range. In sections 89 and 97, the connexions between the range and his theory of the special elevation of the whole region are indicated, and in section 64 the carboniferous limestone is alluded to as well as the formation of the salt marl, and supposed internal changes in it. This marl is referred to the trias or permian age and called "saliferian." The carboniferous are said to be succeeded by oolitic rocks. In the succeeding section the nummulitic rocks are described, their associated alum shales being, it is stated, developed only where lignite is situated close to the "saliferian" formation, and the opinion is expressed that these shales appear to be patches of lignite metamorphosed. In sections 67 to 75, the sandstone, clay and conglomerates, overlying the nummulitic group, are supposed to be miocene, the upper portion being identical with the

* Memoirs of the Geological Survey of India, Vol. V, Pt. 1.

† Kashmir, the Western Himalaya, and the Afghán Mountains, a geological paper by A. M. Verchere, Esq., Beng. Medical Service, with a note on the fossils by M. Édouard de Verneuil, Memb. de l'Acad. Scien., Paris. Jour., As. Soc., Bengal, Vols. XXXV and XXXVI, Pts. 2 and 2, 1866-67, with maps and illustrations.

Siwálik rocks. The position of the Salt Range *Ceratites* is discussed in section 76.

At sections 92 and 93 the gypsum and salt marl of this district are again noticed, and an anticlinal arrangement of beds at Márí on the Indus mentioned, as shewing conformity of the "saliferian" under jurassic rocks and an unusual dip of the *silurian** and jurassic beds on both sides of the anticlinal. It is suggested that these local upheavals may be due to swelling of the gypseous beds from the change of anhydrite into common gypsum.

Manuscript, 1869.

A manuscript paper by the same author on the district of Banu and neighbourhood, in referring to part of the Salt Range, repeats his triassic classification of the salt marl, impugns the correct conclusion of Dr. Fleming, that it was inferiorly placed with regard to the carboniferous series, and concludes with the statement that no older rocks than carboniferous are present.

M. de Verneuil, 1864—1867.

In M. de Verneuil's note to the paper of Dr. Verchere† will be found several very interesting remarks upon the fossils sent to Europe by the latter, mostly from Kashmir, but some identified with Salt Range forms. The author also refers to the species forwarded by Fleming, Purdon, Godwin-Austen, and Verchere, and shews the wide range of some of the Salt Range forms; for instance,—

Athyris (*Terebratula*) *subtilita*, Hall, found also in the carboniferous of Great Salt Lake, Utah, America.

Productus longispinus, Sow., found also in Ohio, Kentucky, England, Spain, Belgium, Russia, in the Governments of Tiver, Kalonga on the Donetz, and on the River Belaja, near the glacial sea.

P. Cora, D'Orbigny; found also in England, Belgium, Spain, and in Russia, on both slopes of the Ural, &c., as well as in North America.

* *Silurian* is evidently a misprint in Dr. Verchere's paper for *Saliferian*.

† Dr. Verchere's paper already noticed.—J. A. S. B., Vol. XXXVI, year 1867.

P. semireticulatus, Sow., also in Europe (Russia) and America, in Siberia, and in the Altai Mountains.

P. costatus, Sow., also in England, Russia, and Missouri.

P. Humboltii, D'Orb., Salt Range, and western slope of the northern Ural Mountains.

M. de Verneuil speaks of Russia, the Ural, and the Altai as links between India and England as regards the organic remains referred to.

Baden-Powell, 1868.

In his large work on the economic products of the Punjab,* Mr. Powell, apparently following Dr. Fleming, states that the principal beds of salt occur in the Devonian group on the southern side of the Salt Range. From Dr. Fleming's reports he extracts the full description of the working of the mines. The Range, its geographical position, the positions of its adjacent ridges, and its geological structure are described.

At page 13 Mr. Powell states, apparently as an extract from Dr. Fleming, that grains of native platinum are found in the same way as the gold in the Indus, being called by the natives "white gold," and that they despise it exceedingly. In Dr. Fleming's "Trip to Pind-Dadun-Khan, &c.,"† (at page 682), he says, from repeated inquiries among the gold-washers, he could not discover that platinum occurred. This is in accordance with my experience.

A. B. Wynne, 1870.

A short descriptive paper by myself on the structure of Mount Tilla, at the eastern end of the range, appeared in the Records of the Geological Survey.‡ The series as exposed here differs greatly from the development of the rocks further westward.

Mr. B. S. Lyman, 1870.

Mr. Lyman was deputed to furnish a special report upon the mineral oil of the Punjáb and its sources. The field of his operations lay chiefly north of the Salt

* Economic Products of the Punjáb, by Mr. Baden H. Powell, C.S., Vol. I, pp. 12, 69, and 130, &c., 1868.

† Jour. As. Soc.; Beng., Vol. XVIII, p. 682, July 1849.

‡ Records of the Geological Survey of India, Vol. III, No. 4, 1870.

Range, but he had opportunities of seeing parts of it, particularly the Jaba petroleum springs, at the west end and northern side of the range. The structural geology of these oil localities are treated at length in his report, to which sections and small maps are appended.*

In a subsequent paper† the same author makes several allusions to the physical geology of the range and of the neighbouring country, and mentions also the useful minerals.

H. Warth, 1871.

Among the appendices to the *Annual Report of the Customs Department for the official year 1869-70,* is a report by Dr. Warth upon the Mayo Salt Mines region at Kheura,‡ one of the most important of the Salt Range mining localities.

The report gives a very detailed description, first, of the geology of the environs; secondly, of the hill in which the salt mines are situated; it then treats of the mines, their present and future mode of working; and concludes with chemical analyses of the salt.§ Vertical sections are also given shewing the arrangement of the strata and position of the mines in profile.

The author divides the rocks into two main groups, the "sandstone" and "salt" formations, these being again sub-divided into seven smaller divisions.||

Living upon the spot and with many opportunities of acquainting himself with details, Dr. Warth has left little unsaid about the locality.

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* General Report on the Punjáb Oil Lands, by Benj. S. Lyman, Government Press, Lahore. 1870, p. 38, &c.

† Topography of the Punjáb Oil Regions, by the same author, Trans. Amer. Phil. Society, Vol. XV, 1872.

‡ Report on the Administration of the Inland Customs Department for the official year 1869-70. Appendix H, by Dr. H. Warth, Chemical Analyst, Inland Customs Department, since appointed Collector of the Salt Range District.

§ From Mr. M. Hickie's pamphlet on Customs; also analyses, by Cornelius Hickie, Esq., Chemical Analyst, Agra.

|| The following is the list which is given of all the strata, from above downwards, by Dr. Warth:—

	Thickness.	Average.
Recent formation.—Debris of Gypsum, &c ...	100′—200	150′
Limestone formation.—Nummulitic limestone	...	200′

Considering this more from a mineralogical than a geological point of view, he has dwelt at greater length upon the mines, mineral productions, and immediately associated rocks, than upon the geological succession; and were it not for his minute and accurate survey of the mines, the stratigraphical relations of the salt deposits here would have remained longer unknown.

His report for 1870-71.

Another report by Dr. Warth forms the "*Appendix D*" to the next "*Annual Report of the Inland Customs Department*" (1870-71, published in 1872). In this the engineering operations of the year are first detailed, and fresh matter added, including a geological description of Jogí Tilla (or Mount Tilla) with reference to a proposed trial shaft (since commenced) in order to discover whether the great salt deposits exist in their usual place beneath that mountain.* A map and sections of the locality are appended.

		Thickness.	Average.
Coal formation.—Coal, alum-shale, and marl		...	20′
Sandstone formation	Green sandstone ...	...	...
	Blue marls ...	100′—150	125′
	Red sandstone ...	400′—800	600′
Salt formation ...	Upper layer of white gypsum	5′	5′
	Brick red marl, or gypsum	60′—200′	130′
	Brown gypsum ...	80′—200′	140′
	Lower layer of white gypsum	200′	200′
	Salt marl and salt ...	600′	600′

Volcanic.—Trap piercing through the lower strata up to the boundary between the upper layer of white gypsum and red sandstone.

	Feet.
Sandstone formation	1,325
Salt formation	1,075
	2,400

The following succession of strata at Mount Tilla is given:—

	Feet.
Nummulitic limestone	70
Variegated strata	80
Green sandstone	200
Dark shales	135
Red sandstone (minimum)	235
Gypsum (minimum)	130
	850

In a passage referring to the brine spring of Kalra, near Bakrála, on the Grand Trunk Road, from Jhelum to Rawal Pindí, the author seems to suppose the existence of a salt-field below.

The third part of the paper is a preliminary report "*Upon the salt-bearing strata in the eastern part of the range from the Mayo Salt Mines to Jogí Tilla.*" The geological structure and physical features of the ground are mentioned, and a succession is described differing slightly from that formerly presented by this writer.*

Dr. Warth corrects Dr. Fleming's statement that "beds underlying the salt marl" were visible; he supposes that this appearance is due to a simple case of slippage, and he states that strata older than the salt marl are nowhere seen.

A fourth part of the report is devoted to the "*Salt mines of the Punjáb Salt Range, west of Pind-Dadun-Khan,*" thus furnishing, in conjunction with former reports, a complete survey of the range so far as the salt is concerned.

The salt quarries of Kálábágh on the Indus are first described, then the geological structure of that part of the range; the alum shale mines and alum factories are next noticed (the latter slightly); after this all the "beats" or preventive sub-divisions of the range as far as Makrach are taken up and treated in detail, the physical and geological features

* One member of the series (ε) formerly included by Dr. Warth with his green sandstone is separated in the following table, which being inverted in the original is here placed in natural order:—

		Estimated thickness.
ϑ	Tertiary strata	1,000 feet.
η	Nummulitic limestone	200 "
ζ	Coal embedded in shales	50 "
ε	Red and green, white spotted shales and sandstones (*vide* Fleming), variegated strata with impressions of salt crystals	150 "
δ	Hard fawn-coloured sandstones with conglomerates ...	400 "
γ	Dark arenaceous shales with green earth	200 "
β	Dark red sandstone, fine-grained	400 "
α	Red marl and gypsum with rock salt	1,000 "

of each referred to, and ample information as to the mines given, together with numerous rough illustrations.

It will be necessary to refer subsequently to various parts of these papers, which, from the amount of information they contain, form certainly the most valuable observations made upon the salt-bearing portion of the Salt Range series. The advantage of having a competent mining engineer and analyst, acquainted with geological structure, resident upon the spot, will doubtless be felt in connection with future operations. These appear likely to be carried out on a larger scale than hitherto, a wire tramway from the Mayo Mines crossing the Jhelum at Chak-Nizam having been erected (under the superintendence of Lieutenant de Wolski, R.E.), and surveys on both sides of the river having been made for a branch line from the Northern State Railway.

Markham, 1871.

In an able memoir upon the Indian Surveys* by Mr. C. R. Markham, C.B., there is a passage at page 105 upon the Physical Geography of the Upper Punjáb, in which the Salt Range is slightly mentioned.

Wynne and Warth, 1873.

A very full collection of the Salt Range minerals and a complete set of petrological specimens illustrating the structure of the range at Kheura, from the lowest salt upwards, was forwarded to the Vienna Universal Exhibition of 1873 by the Geological Survey of India. In making this collection Dr. Warth rendered much valuable assistance, and furnished a solid rectangular mass of salt from within the mines, of about two tons in weight. This large specimen was taken to shew the general character and stratification of the salt, which it did very perfectly; it arrived safely at Vienna, *viâ* Lahore and Calcutta, and was left there.

Oldham, 1873.

Dr. Oldham, while he was officially engaged upon the arrangement of the East Indian mineral products at the Vienna Exhibition, noticed (in a communication published

* Printed by order of H. M.'s Secretary of State for India in Council, Allan and Co., London.

in the *Ver. Der Geol. Reichsanstalt*) the position of the rock salt of the range and its silurian age, being thus the oldest of known salt deposits.

H. F. Blanford, 1873.*

In Mr. H. F. Blanford's Physical Geography for the use of Indian Schools,* a slight reference is made to Salt Range geology. The upheaval of the range is referred to the period when the Siwálik hills were formed, or perhaps later, and a similarity of certain of its formations to those of the Himalaya around the Spiti and Sutlej valleys is noticed.

Tween, 1873.
J. Wiener, 1874.

While the minerals for the Vienna exhibition were being collected from the Salt Range in 1873, the interesting discovery was made by Dr. Warth of potash salt in an impure saline bed separating two of the thick salt seams of the Mayo mines. An analysis of the mixed salt by Mr. Tween of the Geological Survey of India, was given in the catalogue of the collection (published at Her Majesty's Stationery Office, London, 1873), page 8. A notice of this potash salt, containing sylvine and kieserite, and a description of the mineral by Mr. J. Wiener, will be found in a translation by Mr. V. Ball from the *Jahrbuch der k. k. Geologischen Reichsanstalt* (XXIII, No. 2, p. 136), in the Records of the Geological Survey of India.† The hardness and cleavage of the kieserite are stated to be the same as those of the Hallstadt mineral of the same kind.

A. B. Wynne, 1874.

A paper of mine in the Quarterly Journal of the Geological Society of London,‡ with special reference to the "junction in the Upper Punjáb, between the outer Himalayan tertiary rocks and those forming the hills," has several allusions to the geological features of the Salt Range. The conformable sequence of the tertiary rocks and the parallelism which

* Published in Calcutta and London.

† Vol. VII, Pt. 2, p. 64.

‡ Qtly. Jour., Geo. Soc., London, Vol. XXX, Pt. 2, p 64. I should have quoted Dr. Stoliczka's Taglig limestone, in table facing page 62, as Liassic.

obscured any recognisable break between the Salt Range eocene (nummulitic) and overlying sandstone and clay series, are mentioned. A section through Diljaba mountain is given for comparison with the Dandli section of Mr. Medlicott's Sub-Himalayan Report; but subsequent examinations have so altered the reading of the latter that much of the disparity noticed has been removed, and if the Dandli hill limestone had proved itself nummulitic by any fossil remains the similarity between the two sections would be striking.*

The suggestion at p. 69 regarding possible differences connected with the production of the Himalayas of the Simla area as compared with those mountains nearer to the Upper Punjáb appears to coincide with the later and bolder announcement of Mr. Medlicott, that these two areas of the Himalaya have been elevated at different periods. (Records, vol. ix). I did not venture to say so much. The elevation of the Salt Range was doubtless connected with that of the Western Himalayas.

A. B. Wynne, 1875.

In the memoir on the Trans-Indus Salt Region† I have referred to the geology of the Salt Range where closely connected with the subject under consideration. When this memoir was published, I was absent on furlough and had not the opportunity of either correcting the proof sheets or bringing some of the observations into connection with the most recent views developed by the Survey regarding other regions geologically connected with this. Thus the classification of the upper tertiary beds was influenced by the supposed discovery that the Siwalik fauna extended downwards far into the Nahan group. On more recent information the Upper Tertiary beds should have been shewn in the table at page 24 as SIWALIK instead of NAHAN; and the rocks immediately below these,

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* See Mr Medlicott's paper, Records, Geol Survey Ind., Vol. IX, p. 49. This limestone is supposed to be carboniferous. Paper on the Pír Punjál. Lydekker, Records, Geol. Surv., Vol. IX, p. 157.

† Mem. Geo. Sur Ind., Vol. XI, 1875.

at least as far down as the nummulitic limestone, would have been classed as NAHAN.

H. B. Medlicott, 1876.

In his recent paper upon the Jamu country* Mr. Medlicott describes at some length the changing structural features of the intermediate tertiary region, between his Sub-Himalayan district and that occupied by these rocks in the Upper Punjáb.

The paper has an important connection with the geology of the upper series of the Salt Range, and requires to be carefully considered, because it differs greatly from any previous attempts to apply the eastern structural arrangement to the Western Punjáb part of the Himalayan border zone of tertiary rocks. In both regions the differences of stratigraphical structure, embracing succession or discordance, had been as well known as that identical groups occurred in both.

The principal points bearing upon the Salt Range tertiary sandstones, &c., are the following:—

All the breaks, faulted boundaries, discordances, or marked unconformities separating the different tertiary zones in the south-east become altered and die away in their extension to the north-west, so that the groups found in the Upper Punjáb succeed each other with perfect parallelism at the Salt Range as well as elsewhere in this country. This regularity of sequence I had often noticed and referred to—see papers on the Upper Punjáb.†

Even the unconformity of the Sub-Himalayan eocene Sabáthu group on the older Himalayan series likewise dies out, and the Sabáthu beds in this northern region rest with as perfect parallelism upon older limestones of unknown age in Púnch, as I had observed them to do upon

* Records, Geol. Survey, Ind., Vol. IX, p. 49.

† Records, Geol. Survey, Ind., Vol. VI, pp. 60, 68, Vol. VIII, p. 48, and Quarterly Jonrl. Geol. Soc., Lond., Vol. XXX, p. 61, 1874.

the hill limestone of Khairí Múrut,* westward of Rawal Pindi, or, indeed, as the Salt Range nummulitic limestone rests on underlying rocks.

But a break is mentioned at the top of this Salt Range nummulitic limestone based upon the occurrence of a layer with limestone and flint pebbles just below the junction with the overlying sandstones, &c.: the parallelism between the two remaining still as prominent as elsewhere in the whole series. I have long sought for evidence in favour of this supposed unconformity, but have never been able to prove it completely by any denuded surface of the older rock; the junction layer spoken of where I have seen it, appeared made up of fragments not distantly derived. West of the Indus, indeed, I believe a peculiar sudden transition takes place.†

A suggestion is made that the Salt Range nummulitic limestone represents that at the bottom of the Sabáthu zone, strong indications of the connexion occurring in the hæmatitic clay and coal bands at its base.‡ The Nahan fauna is declared still unknown, and it is noticed that the ossiferous Mammalian beds are all Siwalik. The Sirmúr triple group referred to is not represented in this country.

A new sub-division is introduced to receive the Upper Siwalik conglomerates; and a post-tertiary conglomerate series (which has representatives near the Salt Range) forms an unconformable group, intermediate between the tertiary beds and the alluvium. Hence, the only tertiary sub-divisions near the Salt Range will be nummulitic, Nahan and Siwaliks, the latter comprising lower and upper groups.

It will be seen from the foregoing account of previously published matter relating to the geology of the Salt Range, that it is hardly an easy task to furnish a report, brought up to date, which shall not in too great a measure repeat the observations to be found in former papers, nor yet leave unnoticed circumstances of importance. Differences in the conclusions arrived at have been generally suppressed in the preceding notes, but statements of contrary views will be found further on.

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* Believed to be nummulitic in part, if not all.

† On Mount Tilla, Rec. Geol. Surv. Ind., Vol. III, p. 83. Mems. Geol. Surv. Ind., Vol. XI, Pt. 2, p. 65, and several junctions in detailed descriptions.

‡ Memoirs, same vol., p. 139.

CHAPTER II.

PART I.

PHYSICAL FEATURES.

A prominent feature of N.-W. India.

OF itself, the Salt Range forms a prominent physical feature of North-Western British India, rising between the flat plains and *thal*, or desert, of the Lower Indus basin and the elevated Potwar* plateau embayed between the outworks of the Himalaya, Hindú Kúsh and Afghán mountains. It rises above the adjacent tracts, but with a considerable relative difference of altitude on either side, as do the Western Ghâts above the Deccan and low coast plains, or as the Himalaya range itself rises above the high plains of Asia on one side, but stands at a much greater difference of level above the low plains of India on the other. One analogy with the latter range as to some physical peculiarities might even be carried further, the general watershed of the adjacent countries in both cases lying northward of the principal elevations and both being bordered to the south by a fringe of coarse deposits brought down by swollen torrents from the hills.

Here, however, the physical analogy ceases; the aspect, stratigraphical structure and forms of the two regions being even more dissimilar than are their respective heights. Formations of the same geological age have, it is true, been found in both, and some few fossils from each have been pronounced identical, but the petrographical characters of the rocks are totally different.

Its features.

The essential feature of the salt range is that it forms a bold escarpment to the southwards, this character being obscured in some places, by reason of the contorted state of the rocks, and in others very promiment, presenting a

* This plateau has several divisions with different names, but that of one of them, the Potwar, is often applied to the whole of the ground lying immediately north of the Salt Range.

fine façade of lofty cliffs, bluffs, and precipices overlooking numbers of steep valleys and penetrated by profound ravines or gorges,* some of which almost deserve the name of cañons.

These features contrast strongly with the flatness of the plains below and with the undulating or hilly plateaux which for 76 miles crown the acclivities, or with the more gentle northerly slopes intersected, as they descend to the Potwar, by an intricate labyrinth of deep, narrow, often vertical-sided ravines, such as are rarely seen save in this region, and which have won for it the special name of *Kuddera*,† from inhabitants generally unobservant of natural features, and often ignorant even of the names of those beyond their own immediate locality.

Southern escarpment.

The southern escarpment is strongly marked along most of the range, rising to an average height of 2,200 feet above the plains at its foot, which are seldom more than 750 feet above the sea. Lofty portions of it also look down upon the Potwar plateau, the edge of which (with heights averaging 1,824 feet) does not reach to within 1,074 feet of the mean height of the Salt Range.

The Potwar.

A very gradual increase of these heights takes place westwards towards the most elevated summit, Sakesar, which is situated 36 miles from the western extremity of the range at the Indus. Here the general elevation is 4,500 feet, and the summit itself has an altitude of 5,010 feet.

Variety of form of range.

But the Salt Range is not entirely a simple elevated tract strongly scarped on one side and surmounted by undulating open plateaux. This is its character in the central

* This word "gorge" is frequently locally used in speaking of the deep throat-like "gulches" of the range, to which it appears very applicable.

† A narrow valley in this part of the country is called a "durra" kus or "khud"; the affix is taken to mean a multiplicity of forms. A large glen or stream course (dry or otherwise) is called a "Waan" or "Vaan"; as Nīla Waan, the blue valley, named after the colour of its stream as seen from above.

region, except that the northern sides of its plateaux are commanded by a minor escarpment facing to the south. At each end of this upland country the features change considerably; in the east one or two conspicuous hills rise above neighbouring portions of the range, while to the west the ridges enclosing a flat depression, called the Son, converge, and unite with the superior mass of the peak Sakesar.

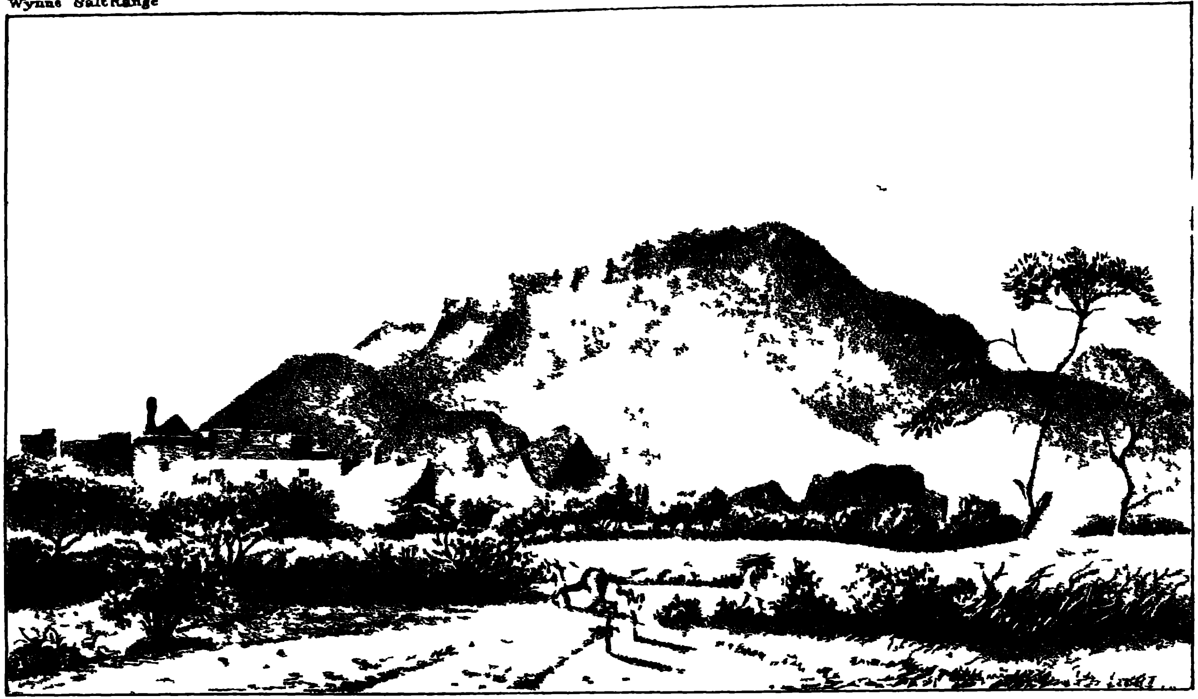
From Jalalpur to eastward.

Eastward of Jalálpur the extension of the principal ridge becomes distorted, and sinuous, and is cut through by the channels of two considerable rivers, the Búnhár and the Kahán; Mount Tilla, one of the most lofty eastern elevations, occurring at the part interposed between these streams. This Mount Tilla ridge is generally between 3 and 4 miles broad, it averages nearly 2,000 feet in height, and culminates at Jogi ka-Tilla in an elevation of 3,242 feet. Just to the westward of this, where the mountain is highest, its width is barely above a mile. The Chambal portion of the Tilla chain, nearest to Jalálpur, rises to 2,290 feet, has a north and south direction, bending towards the west, where separated from Mount Tilla by the Búnhár gorge, and, declining by successive ridges eastward, dies out in the alluvial flat of the Jhelum near the Grand Trunk Road eastward of Rotás.

Mount Tilla.

Bakrála ridge.

From the northern side of the range at a point N. 10° E from Pind-Dádan-Khán, an important spur, separated by a deep gap from the main mass, leaves the latter and stretches for more than 30 miles in a north-easterly direction. Close to the range, where it forms the Diljaba mountain, this spur has a height of 3,052 feet, but further on it declines to heights averaging 2,336 feet, and it has been called the Bakrálá Ridge from the Pass of that name on the Trunk Road. Its highest point in this neighbourhood is Nili Hill near Doméli, and the ridge having a general width of 2 or 3 miles may be said to end in the broken hilly ground extending for some distance from the right bank of the Jhelum in the vicinity of Léhri.



J Schaumburg Lith

COMMENCEMENT OF SALT RANGE ESCARPMENT AT JALALPOOR

INCLINED TERTIARY ROCKS NEAR THE TOWN AT FOOT OF HILL

From Jalálpur for 16 miles to the W. N. W. the escarpment of the main range is very plainly marked, rising gradually in height from 1,852 feet to 2,275 feet (the level of the neighbouring part of the Jhelum river is about 700 feet), and the width of this part of the range steadily increasing westwards from 2½ to 6 miles.

Changes in the escarpment.

One of the most remarkable features of the eastern part of the range is that the strongly prevalent southerly escarpment changes sides, so to speak, at Chambal mountain north of Jalálpur (where the strata have been most enormously disturbed and faulted), an easterly dip of the beds giving a westerly aspect to that portion of the scarp. At Mount Tilla, a few miles distant, the southerly aspect is regained, but at the Diljaba end of the Bakrála ridge the scarp faces the north-west, and again at Kárangli hill, overlooking the Choya-Saidan pass, a strongly marked westerly escarpment occurs. This hill, 3,526 feet high, and that of Chel near it, 3,701 feet, seem to be both displaced portions of a south-westerly extension of the Diljaba and Bakrála ridge. Such variation in the forms of the hills indicates, as might be supposed, corresponding disturbance which will be noticed in its proper place.

Remarkable feature.

Another remarkable feature is that the direction of the whole range changes abruptly near Sakesar, nearly at right angles to its (east-by-north to west-by-south) course. Here it becomes very suddenly narrow for about 9 miles, bears to the north-west-by-north, and loses in height, averaging 1,727 feet (with a summit near Namal of 2,260 feet), and a width of two miles and less. This abrupt change corresponds to features in the Trans-Indus extension of the range, both together forming a deep, wide, and open sinus in the hilly margin of the Indus plains, where that river debouches from the mountains. This change is, however, more closely connected with the general orography of the Upper Punjáb than with the Cis-Indus Salt Range, though it forms one of its most peculiar features.

Another remarkable change.

Tredian hills.

Beyond the narrow part the range expands into the Tredian hills, reaching to within a few miles of the Indus, and having a width of 8 miles near Swás, but diminishing as the river is approached. They have an average height of 3,087 feet, and their highest point is reached at Tredian itself, 3,477 feet.

Disappearance of the range proper at the Indus.

At the debouchure of the Indus upon the plains the Salt Range may be said in most senses to disappear for a space in a way difficult to account for satisfactorily, a few small and disconnected hills only remaining to represent it. The chief of these detached portions, formed of the most perishable materials of the whole series of the range, is the salt hill of Mári, consisting of red marl, gypsum, and rock salt, and having an altitude close to the river's bank of 1,921 feet.* The geological and physical relations of the Salt Range re-appear in some measure Trans-Indus beyond the limits of this district.

Plateaux.

As one continued massive feature the range may be said to commence at its eastern plateau, where the high ground from Jalálpur, rising gradually from the Búnhár river, meets and almost joins the Diljaba portion of the Bakrála ridge: from hence westward nearly to the summit at Sakesar, high plateaux form its crest. These may be called the Eastern plateau, the Dandót plateau, the Kahún, Málót, Núrpúr, and Sôn plateaux.

Eastern plateau.

The "Eastern plateau" extends westward to Pid, a distance of nearly sixteen miles, with a width of from one to eight miles and heights of from 2,100 to 2,800 feet, the width of the whole range here being from 7 to 10 miles. The surface undulates, being frequently of bare rock, worn waist-deep into closely adjoining furrows. The plateau is much indented by the heads of valleys along its south-eastern side, and bordered in the opposite direction by

* Dr. Fleming's List of Altitudes, 2nd report, p. 449. (No heights are given on the field maps.)

the hill of Chel and by an open shallow valley, beyond which the conspicuous peak of Kárangli overlooks the northern entrance to the pass of Choya-Saidan-Shah. From this peak a series of south-westerly ridges and valleys divides the plateau from the next, and terminates in very broken ground surrounding the small but lofty plateau of Dandót, part of which is 2,599 feet above the sea.

Dandót plateau.

Next to the westward is the Káhún, which might also be called the Dalwál plateau, with heights of over 2,400 feet. It is less rocky than those previously mentioned, is bounded on the north by steeply sloping rocky "*Kuddera*," and southward by two remarkably long, straight ravines, meeting at an obtuse angle and forming the deep gorge of Makrách. This upland is 16 miles long and 8 wide, the whole range having here gained so much in width as to be 12 miles broad.

Kahún plateau.

On the south-west side of the Kahún, a lofty, narrow, and irregularly shaped plateau extends in a north-westerly direction, between one of the ravines just mentioned and the southern slopes of the range. It rises to elevations of 3,000 and 3,200 feet, and may be called the Malót plateau.

Malót plateau.

Separated from that last mentioned by the deep Sardi (Sera or Seriarik) gorge is another larger table-land on which the village of Núrpúr stands. It is in parts less rocky than the last, and has much the same character as that of Dalwál. The elevation of the surface ranges from 2,500 to 2,800 feet. This Núrpúr plateau is about 10 miles from north to south and the same from east to west, the whole range here having a width of 14 miles.

Núrpúr plateau.

The high plateau-country stretches to the westward for 32 miles, becoming narrower about Pail and Chámil, where the whole width of the ridge is about 12 miles.

Sûn or Western plateau.

Still further to the west it becomes much wider, and includes the large tract called the Sôn, reaching to the foot of Sakesar peak, under which is situated the Sôn-Sakesar lake at an elevation of 2,526 feet.

In parts this table-land resembles a sea of huge limestone billows, particularly where it is intersected by the east and west chain of the Patial hills. South of this chain lies a somewhat less elevated and more broken tract, traversed by deep ravines leading down to the plains. The Patial hills rise towards and coalesce with the high mass of Sakesar, as do also those which bound the northern side of the Sôn pleateau, upon which heights occur of over 2,900, 3,000, and 4,000 feet. The width of this plateau from north to south is about 14 miles, that of the whole range having increased to 18 or 20 miles. The Sôn possesses a reputation for coolness of climate equal to that of Kashmír.*

Gredi hills.

A large spur or lobe of hills,† leaving Sakesar, flanks for some miles the narrow part of the range which trends to the north-north-west, as if to continue the southern side of the Sôn plateau, but it is much more broken, and has little or nothing of the plateau character. It is separated by a long and deep valley from the narrower part of the range and it rises to a height of 2,899 feet above Chiderú.

Country on each side of the range.

From the summit of Sakesar the eye ranges widely over the adjacent country. To the south, flat plains and desert stretch to the horizon with a surface to all appearance as level as that of the sea, being broken only by the great rivers and the distant tops of the Korána hills, a small group near the Chenáb river. To the north the Potwar or Ráwal-Pindi plateau expands beyond the zone of "*Kuddera*" at foot of the range in wide, gentle undulations, upon which, eastwards, heights of 1,600, 1,700, and 1,800 feet are marked

* Dr. Fleming's Report, p. 396.

† These are the "Gredi" hills of Dr. Fleming (p. 352), and apparently the "Patial" hills of Mr. Theobald (p. 659).

on the maps. North of the Sôn the heights rise to above 2,000 feet, but westwards towards the Indus decline again to 1,200, 1,300, 1,500, and 1,600 feet. Distance and elevation make the ground on this side also appear like a flat plain, but between the undulations are deep intricate *Kudderas* leading to the broad sandy beds of rivers generally nearly dry.

Passes.

The range is traversed by three or four principal passes (not including paths or roads which follow no particular depression). The lowest of these are situated near each end of the range. The Bakrála Pass on the Grand Trunk Road north of Jhelum may have a height of 1,400 feet at the ridge of the same name; that at Ghorágali near Diljaba is a gorge of the Búnhár river at about a height of 1,309 feet; a lower gorge on the same stream at Pind Sevíka may be between 800 and 900 feet high. The long pass of Choya-Saidan-Shah, following the deep valley of that name, one of the few considerable valleys opening on the north side of the range, is an old route from Pind-Dádan-Khán northwards; up this the road rises among the intricate and deeply excavated ravines of the range to a height of about 2,000 feet at its crest. The deep gorge of Sardi nearly intersects the range southward of Kalar Kahár lake, but the road which crosses it here climbs the right side of this deep defile below Sardi village.

The last of the passes worth mention as such is that from Namal to Músakhél, above the right bank of the impassable Bakh ravine and at a little distance from it. It probably does not ascend so much as 500 feet above the plain to the south.*

Valleys.

The valleys of the range are numerous, and some of them profound gorges, but none have now any important connection with the country beyond it, excepting the deeply cut passages of the Kahán, the Búnhár, the Váhi, a nameless stream near Khyrabád, and the gorge of the Indus itself.

* The elevations of summits and similar points only are given on the maps; those of hollows or crests of passes are not marked, hence they are estimated above.

The latter at Kálabágh is 1,070 feet in width from shore to shore; its depth in the cold weather varies from 15 to 45 feet, the velocity of the stream is 1·64 feet and the discharge 21,200 cubic feet per second.* Its surface is a little over 681 feet above sea level.

There is a wide open valley at the east side of the range, with heights of over 1,100 and 1,200 feet, lying between Mount Tilla and Bakrála ridges. It is traversed by both the Kahán and Búnhár rivers, having no stream exclusively its own. A portion of this valley or depression occupies a recess where the Búnhár river spreads before escaping through the Pind Sevíka gorge. This, the Choya-Saidan glen, an open basin on the Núrpúr plateau, and a small but deep coomb-like depression beneath Vasnál, are the only glens of importance opening northwards, all the rest being ravines or surface stream-courses, which are more numerous than usual on account of the softness of the rocks traversed.

The whole southern face of the range is cut up by numberless ravines and deeply penetrated by many precipitous excavations, eroded to a depth of several hundred feet lower than the escarpment of the table-lands. One of these gorges bifurcates at Makrách, where it may have a depth of more than 1,000 feet. Another is the fine glen of Sardi (Sera or Seriarik), apparently some 1,500 feet in depth, where its width is little more than a mile, and even much narrower near its mouth, though equally deep; but the grandest chasm of all is that of the Nílawán, cut out of the Núrpúr plateau. This varies from a quarter of a mile to a mile in breadth, and penetrates the range for a length of about 5 miles from its narrow mouth. Its depth is unknown, but may be guessed at 1,500 to 1,700 feet.

Other fine glens of the same character are—that leading south from Pail, the Narsingphoar ravine, the Sanglewán not far to the westward, the Jábi gorge from above Kávhád, the glens of Varchá, Amb,

* From information kindly supplied by D. McMordie, Esq., C.E., when engaged upon a projected canal from Mári southwards.

J Schaumburg Lith

SOUTHERN ENTRACE TO THE BAKK RAVINE MJSAKHEL

IN CARBONIFEROUS MESTONE

and the singularly inaccessible cañon called the Bakh ravine, which intersects the whole range near Namal, having a length of about a mile and a fall of nearly 350 feet (judging from the heights upon the map).

There are features connected with this ravine which make it appear strangely placed at this point. The streams which now discharge through it look too small to have cut so large a gorge, even though this may have been commenced when the ground to the north was less worn down by denudation. The occurrence of boulder beds near where the great rivers leave the Himalayas, and the existence of an unconformable boulder accumulation at the north-eastern side of the ridge close to the town of Namal, at the commencement of the ravine, would suggest the possibility of this glen having once been a channel through which a larger stream from the north, perhaps the Soán river, found its way southwards before the gorge of the Indus was sufficiently reduced and cut backwards to take off the main body of meteoric water at a higher point.

At present the Golár and Thrappi rivers, which unite and discharge through the Bakh ravine, drain a comparatively small area north of Sakesar summit.

All the streams from the Tredian hills run in steep narrow gullies or gulches, those to the south especially, and one of these has eaten for itself a cavernous passage beneath a massive rocky spur; they are sometimes quite impracticable to follow up on foot.

Water-parting.

The water-parting or "divide" of the range lies north of the principal crest or edge, belonging indeed partly to the Potwar plateau. For some 45 miles in the central portion it separates the heads of tributaries to the Indus from those of torrents which tend towards the Jhelum, but never reach it, as surface streams.* From other parts of the range the drainage of both

* That from Makrách forms a doubtful exception.

sides finds its way southward, and notwithstanding the elevation and continuity of the chain, it forms no considerable barrier to the general southerly outflow of waters from the north, this northern drainage completely traversing it at two places to the west, while in the east the Tilla ridge is likewise twice intersected, and that of Bakrála no fewer than five times to afford passage to streams from the Potwar.

From the salt-marl, most of the southern streams are highly saline, those which are least salt being used for irrigation, but very few are either potable or palatable even to the scattered population accustomed to brackish water all their lives.

The hollows of the Sôn Sakesar and Khabaki lakes on the western plateau of the range are open shallow depressions without visible outfall. The basin of the latter is small, but that of the former includes an area of about 60 square miles and occupies a singular position close to the highest elevations.

Salt lakes.

The four salt lakes of the range form quite exceptional features to the general drainage. Three of them are on the western or Sôn plateau; two of these, the Khabaki and Sôn Sakesar,* or Samandar, lakes, in depressions of its northern part; and the other, the Jalár or Jalúr lake,† in the rugged country to the south. These three lakes vary in size with the amount of rain-fall; they have no

* A fault with a north-east and south-west direction was supposed by Mr. Theobald to bring the salt-marl up at the eastern foot of Sakesar, so as to impregnate the water of the lake (see paper already referred to, p. 658); this dislocation could not be recognised on the ground.

† Dr. Fleming, translating the name "Julhur" as Sanscrit for a spring of fresh water, asserts distinctly that the water of this lake, unlike others on the range, is fresh. Rain may have lately fallen and produced this impression when he visited it, for it was subsequently found to be as saline as the others, both by Dr. Oldham and Dr. Waagen, at considerably different dates. The natives of the place considered it *mita*, or sweet, *i. e.*, fresh enough to drink.

Professor Blochmann, of Calcutta, has kindly supplied translations of the following Sanscrit words: "'*Jhalra*,' a spring of fresh water; '*Jalar*,' a thicket or copse." There is no wood now near the lake to render the latter derivation for the name likely, though there may have been once; doubtless there are fresh springs in the vicinity.

J Schaumburg Lith.

Saline spring

Salt marl Hill

KALAR KAHAR (LAKE) FROM THE BUNGALOW TERTIARY SANDSTONE HILLS

outlets, and are all salt or saline, though far removed from and at a higher elevation than the salt-bearing strata. The largest of them is the Samandar lake, about 3 miles long and 1 wide. The fourth, the lake of Kalar Kahár, having a diameter of about a mile and only a depth of 3 or 4 feet, is situated close under the north side of the range. It has no outlet either except when flooded; a neighbouring nala then affords a passage for the surplus water, and sometimes its white saline bed is all but dry.

There may be various reasons for the saltness of these lakes, which differs in intensity, and would seem not to be derived from chloride of sodium only; ordinary precipitation from water, unable to escape except by evaporation, may have caused it. In the case of Kalar Kahár, brine springs at one place have an influence; and with regard to the Sún, the saltness may be due to the former existence of overlying sandstones and clays charged with saline ingredients.

Fresh springs.

Fresh-water springs are not uncommon upon the plateaux or along their borders. Among them may be mentioned those at Choya-Saidan-Shah, the large sacred spring of Katás, that at the Wycher cliff, Dandót, and those of the Verála scarp. The table-lands form a large catchment surface, the rain water falling upon which would produce springs in the usual way. Another sacred spring at Rotás may be connected with dislocation of the rocks. Here fresh-water springs are locally numerous, one of them forming a strong stream which issues from the dry sandy bed of the Kahán river.

Brine springs.

Brine springs in the salt region are no novelty, but one at Kalrá on the south side of the Bakrála ridge near Doméli is situated among rocks, the highest above the salt-marl; it also occurs in a dislocated locality in the bed of a torrent depositing calcareous tufa and forming river-conglomerate (*Kanjár*). The water of the spring is of a milky-bluish opaline tint; it is half saturated with salt (according to trials by Dr. Warth), and forms black and yellowish precipitates. It comes probably from a considerable depth,

otherwise more springs than one might be expected to occur, and its unknown source can only be guessed at.

There is another so-called salt spring in the same range at the southern slope of Níli hill, where a somewhat strong variety of the usual "*Khára páni*" of the country, charged with mixed salts, chiefly of soda, issues in the bed of a rocky nala.

Saturated brine springs occur on the right bank of the Búnhár stream in the Ghorágalí pass (near Diljaba mountain), just where it is most narrow. The source is probably connected with the salt-marl.

The brine spring of Kalar Kahár rises from a patch of this salt-marl in an entirely abnormal and dislocated situation.

The water of streams in the sandy and argillaceous rocks along the north and easterly parts of the range frequently deposits the saline incrustation called "*túr*" or "*kallar*"* in considerable quantities.

Hot springs.

The hot and sulphurous springs of the Bakh ravine have been noticed by almost every one who has visited the place;† indeed, the smell of sulphuretted hydrogen emitted by them is sufficient to attract attention. They occur for some distance from the entrance at both ends of this remarkable miniature cañon, some issuing strongly, others without force; gas bubbles up, and the water, which is covered by a thin film of gypsum, deposits a black tenacious mud used by the natives as a dye for colouring cotton cloth.‡ The sources are probably distant from the surface, and the springs do not occur in one particular formation.

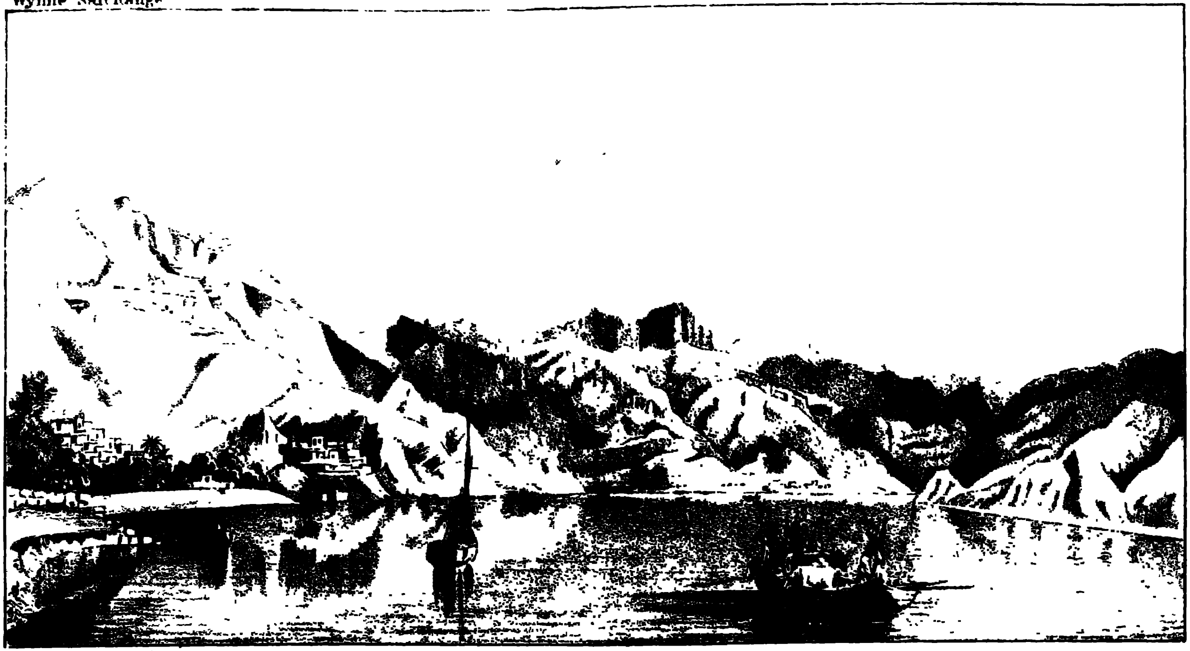
Petroleum springs.

Similar sulphurous springs, sometimes warm, occur here and there in other parts of the range. Two of these close to the Chota and Bara Kata brooks near Jaba (north side

* Sulphate of soda and common salt; Fleming, 1st Report, p. 525.

† MS. notes by Dr. Waagen, &c., &c

‡ See *ante*, Fleming, 2nd Report, p. 265; also Schlagintweit, in Chap. I.



J Schaumburg. Lith.

Town of Kálabágh

Dangot summit

Salt hill of Mári

LOOKING UP THE RIVER INDUS FROM KALABÁGH.

of the western end of the range) bring to the surface a sufficient quantity of petroleum* to enable about 3 quarts daily to be collected, but all is liable to be washed away for the time by floods. From a gypseous deposit here, (thought by some to result from the action of these springs upon the neighbouring limestone,) native sulphur was reported to have been collected; but when I searched for it, the barest traces only could be found.

Aspect.

Viewed from the north, the aspect of the Salt Range is that of a monotonously undulating and not very lofty ridge, upon which some conspicuous summits, such as those of Chél, Kárangli, Tilla, and Sakesar, attract the eye. Closely approached over "*Kuddera*" ground, the range may be often observed covered with scrubby jungle and on limestone slopes by a mass of *Sunketta*† and *Bekekur*‡ shrubs, through which it is difficult to work a passage. Having once left the plateau, almost everywhere on the ascent the bare rock protrudes, presenting a striking uniformity of grey and greenish or red tints, the latter sometimes predominating and sometimes replaced by a dusky orange; all these brighter colours being restricted to argillaceous rocks. On the undulating plateaux small patches of cultivation lie between rocky undulations dotted or covered with *Sunketta* jungle, trees of any size being almost entirely absent everywhere along the range.

Seen from the south, the scarcity of vegetation and the bright colouring of the red, purple, grey, orange, and whitish rocks of the cliffs and slopes, present a strong contrast to the other aspects of the range; the fan-shaped accumulations of detritus at the mouths of the torrent gorges encroaching upon each other to form a stony belt, slightly concealed by thin, starved-looking jungle, which only adds to the sterile appearance of the ground. The whole of this dry and sun-burnt face of the

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* Lyman—"Punjab Oil Lands;" Report to Public Works Department, Lahore Government Press, 1870.

† *Dodonæa Burmanniana.* (Fleming.)

‡ *Adhatoda vassica,* Dr. Fleming's 2nd Report, p. 233.

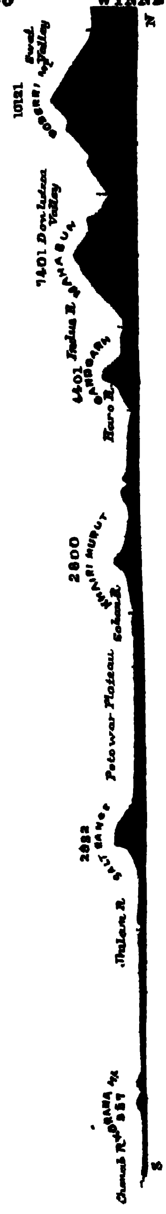


Fig. 1.—Profile of country from Swát to the Chenab crossing the Salt Range near Sardi · distance about 224 miles. Scales: vertical, ¼ an inch = 10,000 ft.; horizontal, 1 inch = 32 miles.

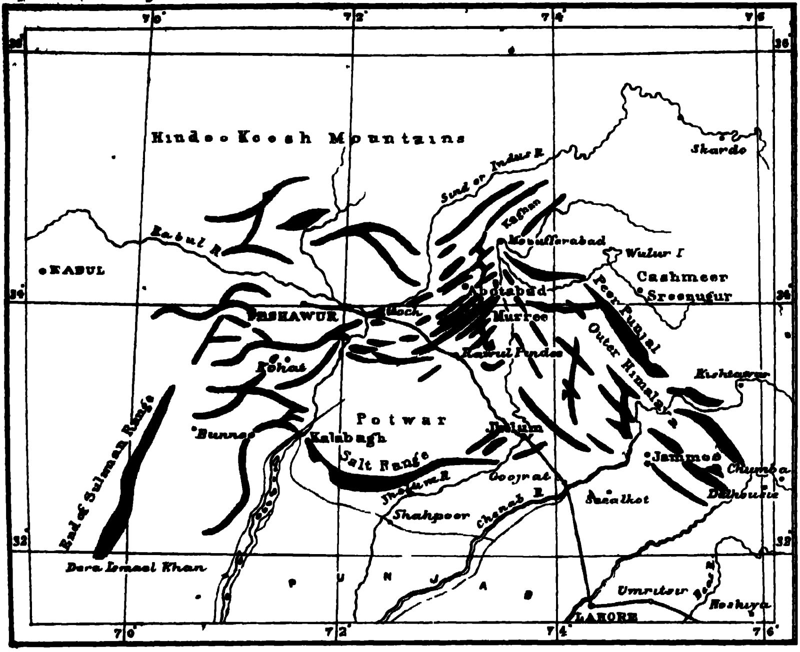
range radiates so much absorbed heat, that an encampment at some distance in the plains, though hot, is found to be cooler than one at its foot.

Picturesque spots occur occasionally, their attractiveness enhanced by their rarity; and there is much that is imposing, though wild, in other scenes. Instances of one or the other may be found in the summit of Mount Tilla, with its ruins and ancient buildings; the rock-pools and gardens of Choya-Saidan-Shah; the antiquities of Katás and Rotás; the lofty village of Dandôt; the neighbourhood of Kalar Kahár, when the vines are in leaf and the lake is full; the grand glens of Nílawán, Sardí, and Nursingphoar; the vicinity of Sodhi near the head of the latter ravine; the deep glen of Ámb; and the gorge of the Indus at Kálabágh, with salt-rock, water, boats, and quaintly piled buildings, making up a brightly-coloured picture, in which the crimson *rol* from burnt alum shale, and duller red salt-marl, contrast with the cool greenish-greys of the lofty *Dangót* cliffs in the back ground.

PART II.

OROGRAPHY AND PHYSICAL GEOLOGY.

As the theoretical explanations of the formation of the Salt Range are included in those relating to the origin of the adjacent mountain regions, I shall endeavour to confine the following observations to features, of which some description may be found useful in considering the local relations with regard to the larger area beyond the subject of this



SKETCH OF POSITION OF SALT RANGE PUNJAB

(Ranges in Black)

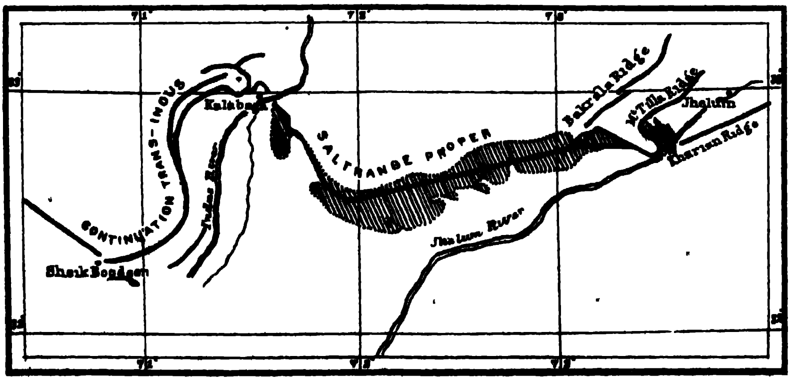


Diagram of Direction of Salt Range. 48 Miles = 1 Inch

report; points which belong to the physical geology of the range must, however, be briefly noticed.

Orographical position.

The situation of the Salt Range is in itself peculiar; it crosses that embayment where the lower ground of Western Hindustán projects into the high mountain regions of Asia, and it forms a separation between two tracts which have very unequal altitudes as seen in fig. 1, a rough profile of the country from Swát to the Chenáb crossing the range near Sardi.

This recess is embayed by the high mountains of the North-West Himalaya on the east, and the Sulimán, Hála, Augustán,* and Khyber mountains on the west; while, to the north, elevated mountainous ground intervenes between it and the snowy ranges of the Hindú Kúsh. In the regions where such great physical features approach and the resultants of their originating forces encountered one another, concentrated disturbance might be expected to produce intense distortion. In the Salt Range this is observable, both stratigraphical contortion on the smaller scale and sinuous curvature of the range itself marking its effect. Including its continuation Trans-Indus, the whole chain appears to have yielded to lateral out-thrust, or forces proceeding from the greater mountain chains on either side, and to have been compelled to accommodate itself to shortened longitudinal limits. (See diagram, Plate VIII, fig. 2.)

The principal or western sinuosity of the range (bordering the Indus for some 70 miles) follows, in a measure, the converging axial directions of the more lofty ranges, its curvature conforming to the angle between these lines.† To the east, however, the strike of the Tilla ridge is distorted so as to fold back upon itself in a curve resembling the letter S.

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* A name applied by natives to the mountains west of the Panjáb.

† Sir Roderick Murchison's mention of the Salt Range as the "first step in ascending from the Lower Pánjáb to the Himalaya" accords with its features, but its parallelism to the Valley of Kashmír and the "mighty Himalaya" is anything but evident. Quart. Journ. Geol. Soc., Lond., Vol. IX, p. 189.

These sinuosities coinciding with escarpments would also suggest undulations in the strata, being arrested by fissures along lines of weakness.

Disturbance.

The two prominent results of disturbance, flexure and fracture, varied according to the intensity of their cause, are commonly observable throughout this region, but complicated flexure is less frequent to the east, having been apparently relieved by numerous great fractures. In the vicinity of Mount Tilla, of the Chambal, Diljaba, and Bakrála ridges, boldly curved beds are often brought into association with nearly vertical strata by means of faults.

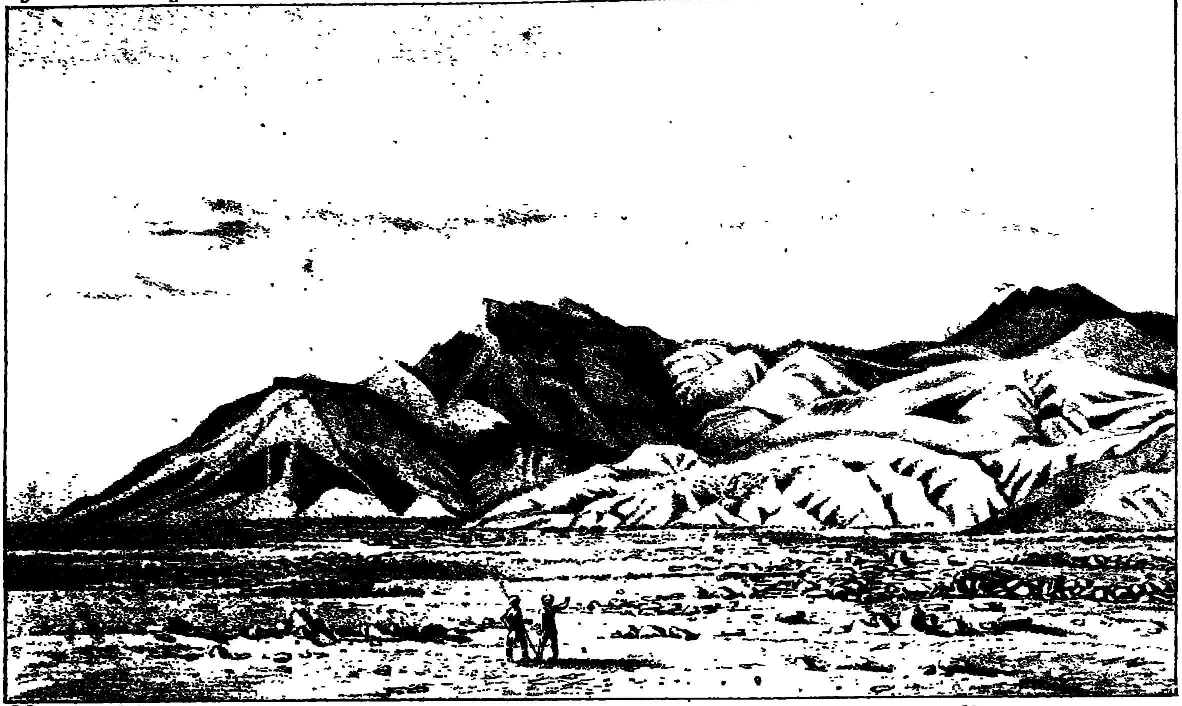
Eastern parts of the range.

Indications of anticlinal structure occur in the Bakrála ridge, and at the Rotás end of the Tilla range, on the eastern side of Chambal mountain and close to Jalálpur, while similar open curves define the eastward commencement both of the Kahún and Eastern plateaux. Between Diljaba and the last named is a decided synclinal in the upper rocks, and the wide valley between Tilla and Bakrála ridges may be called a double synclinal hollow. Besides these larger flexures, small contortions are of frequent occurrence, but few other parts of the range exhibit marked synclinal or anticlinal curvature as essential forms of the mountain structure. And yet the whole chain, from the Eastern plateau westward, partakes broadly of the uniclinal or *incomplete* anticlinal character, the northern side of the curve only being present. It seems reasonable to suppose that the strata once formed a complete arch, but there is no proof whatever that this was the case.

Slight disturbance on the Eastern Plateau.

Greater contortion to the west.

Over the whole of the plateau eastwards, the rocks, though elevated, are but slightly disturbed, hence the tabular forms of the ground; but to the west the rolling wave-like surface is intimately connected with more violent disturbance, each wave representing an anticlinal arch. All the hill country



J Schaumburg, Lith.

Faulted Nummulitic limestone and other groups Fault Salt marl Nummulitic limestone

FAULTS IN HILLS NORTH OF SADOWÁL WEST-CHAMBAL MOUNTAINS (WEST SIDE OF JUTÁNA BEAT)

about Sakesar is a mass of contortions, fractured and disarranged in places; but the narrow part of the range, uniting this mountain with the Tredian hills, is composed of highly inclined beds showing a strong tendency to bend over to the south-west, excepting which this uniclinal ridge has no more indication of anticlinal continuity than the plateau country to the east.

Intense disturbance at the Indus.

In the Tredian hills intense plication again predominates, and the climax of disturbance is reached where the range itself and nearly all of its characteristic formations are lost among dislocations as the Indus is approached.

Northern slopes.

All along the northern slopes, except where deranged by faulting, the disturbance, even where greatest, is regular and the northerly dip constant.

Southern slopes.

The whole southern face of the range presents the most strangely broken and dislocated features, large portions of the lofty escarpment having subsided and smaller land-slips taken place, until the slopes have become often crowded with huge disconnected rock masses at all elevations, in all positions and of nearly all the harder groups, the heterogeneous assemblage being frequently overshot and obscured by debris. This much of the mountain structure is, however, but the result of meteoric denudation assisted by the perishable nature of the soluble salt and gypseous marl beneath.

Faults.

Besides dislocations of this kind there are many true faults, which generally take directions oblique to that of the range: sometimes these coincide so strongly with marked physical features as to become suggestive of cause and effect. Though not susceptible of any very systematic arrangement, there is some parallelism between the fractures lying in courses from west 30° to 35° north, also in another group bearing north-45°-east, the included angle approximating to that at which the range suddenly bends northwards near Sakesar. Other faults assume nearly north and south or east and west directions.

Tilla faults.

A long fault stretches close by the south-eastern foot of Mount Tilla, bringing the lowest rocks there exposed against steeply inclined or vertical beds of the tertiary sandstone and clay series: three minor dislocations parallel to the main one lie between the unbroken uniclinal of the mountain and the master-fault. The displacement here must be large, but cannot be exactly estimated, because of the positions of the rocks. The fault is lost in the sandy gorge of the Búnhár river at Pind Sevíka.

Jalálpur faults.

North of Jalálpur an extensive and most complicated amount of faulting has taken place, bringing the groups at each end of the series into junction, a large branch fracture extending along the western base of Chambal mountain (east) apparently to join the Tilla fault.

Karangu and Diljaba fault.

One of the most considerable lines of faulted dislocation in the whole district coincides very much with the direction of the Bakrála ridge, sometimes lying at one side, sometimes at the other, the line being certainly far from straight, and the whole dislocation appearing like an extended combination of shorter fractures. One of the results of this zone of faulting is the exposure of a mass of nummulitic limestone on the sandstone and clay ridge near Doméli; another is the way in which this limestone disappears at Ghorágali pass, among the overlying beds, the same or a parallel fault occurring here on the north-west side of the ridge. The escarpment of Diljaba mountain is also connected with this line of fracture, which appears to be itself displaced by a cross-fault at the western end of that hill. In the neighbourhood of Chel hill much contortion and great dislocation occurs on both sides of the ridge, but most towards the Potwar country. Whether the fracture is here again connected with the main line or not is obscure, but the fault with its original direction reappears on the north-west flank of Kárangli hill. Here it turns into the Choya-Saidan-Shah valley, bringing the tertiary sandstones against the salt-marl. From this valley the fracture bends down the deep Gamthalla

gorge, its throw having changed sides and the tertiary sandstones, &c., being again brought against the salt-marl on the opposite side from that which they occupy at the mouth of the Choya Valley. The fault is lost in the red marl at Makrách, but another appears to start from the place where it ends, running up the Malkána branch of this gorge to the west-north-west, and terminating, or becoming no longer traceable, at Kalar Kahár. Close to the latter place, and exactly in the line of this fracture, the red salt-marl appears among the nummulitic limestone beds. The throw of this great line of dislocation, it will be seen, varies, changes sides, and in places amounts to nearly the whole thickness of the eastern Salt Range rocks.

Vasnál.

In the neighbourhood of Vasnál, on the northern side of the range, another complex group of faults encloses a hexagonal patch of the red salt-marl surrounded by nummulitic limestone on all sides but one, and there by the overlying tertiary sandstones, &c.; just a fragment of some of the lower rocks above the salt-marl appearing in connection with it.

From this place two lines of fracture nearly at right angles seem to start, one reaching to the head of the Nílawán ravine and bringing a long strip of the tertiary sandstones, &c., against the underlying limestone. The other appears to extend by Badráe to beyond Dheri, where another complicated system of partly concealed faults exposes the red marl and some of the overlying rocks.

Nílawán, &c.

Down in the bottom of the Nílawán ravine, crushing and faulting again appears, as also in the glen leading from Pail to Kutta, and another fracture coincides with the glen of Nursingphoar.

Kávhád.

A long fracture, too, extends up the nearly straight Kávhád glen from near Jabi in a north-east direction, and meets a series of faults at first bearing north-east south-west, but afterwards taking a westerly direction along the cliffs near

Jalár, and to the north of that lake, sending off a nearly parallel branch. The main fracture extends to the head of the Ámb glen, passing down which it is lost among a multitude of parallel and other dislocations.

Chiderú.

In the Chiderú hills again faults abound, and also in the Tredian hills to the north-west; all the fractures between Kávhád and those of the last-named hills uniting with the frequent minor dislocations, to produce the greatest confusion, amidst which the true succession of the rocks can only with difficulty be traced.

Mári.

The most extreme result of the faulting of the range is the mysterious, almost total, and abrupt, disappearance of the whole western series intermediate between the tertiary sandstones and clays and the salt-marl. From near Khyrabád to the Indus, the faults themselves by which this has been effected have left such slight traces to mark their course that, were it not for the disturbance of the ground and the re-appearance of the series beyond the Indus, discordance would have to be inferred in order to account for the absence of the intermediate strata in this neighbourhood.

Elevation.

If the range formed a simple symmetrical anticlinal curvature, its origin would be as easily explained as that of other mountains similarly constructed by the hypothesis of lateral pressure, in some cases accompanied by the settlement of the mass; but while the disturbance evidently tended to produce common anticlinal curvature, it only partially succeeded, so far as can be seen, and produced instead the uniclinal structure described, with a more or less strong resemblance to the features of certain of the Sub-Himalayan hills bordered by fissures or what would amount to faults, if not in some cases absolutely dislocations.

This resemblance is nevertheless incomplete, in so far that the sections across the Sub-Himalayan ground expose the boundary fissures and adjacent structures, but in the Salt Range nothing whatever is known

of the rocks concealed along its southern foot or their positions.* The Korána hills, forty miles distant, afford the nearest evidence in this direction, and there the principal ridge, according to Dr. Fleming,† has a uniclinal structure and northerly dip, like the Salt Range itself.

The effort to recall a former state of things has been made by Dr. Fleming ‡ in treating of the upheaval of the range, and again in an elaborate manner by Dr. Verchere § when writing of the larger adjacent area. Dr. Fleming supposes three subsidences and elevations to have taken place before the great elevation of the whole range; in the Miocene period or subsequently, and contemporaneously with that of the Himalaya. He also considers that the upheaval extended from east to west.

Dr. Verchere contends that the whole of the embayed ground between the border ranges of North-West India was uplifted into an open arch or dome-shaped anticlinal bordered by fissures, along one of which, perpendicular to the others, the arch was broken down, leaving the Salt Range as its uptilted extremity. Both of these authors, Mr. Theobald,¶ Mr. Medlicott,|| and Mr. H. F. Blanford** agree in attributing the elevation of the range to later tertiary times,—

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* No deep borings are known in the vicinity of the Salt Range : the wells for the piers of the railway bridges on the Jhelum and Chenáb rivers are entirely in detrital deposits, and these deposits only have been found in a boring at Ambála between the Indus and Ganges basins. This boring has been put down to a depth of 700 feet, the altitude of the locality being 919, so that the bore-hole has nearly reached sea level.—Professional Papers, Roorkee (Rúrkí), No. 12, vol. ii, Major Thackeray, R. E.

† Authority cited, p. 446.

‡ Au. cit., p. 364.

§ Ditto, p. 89.

¶ Authority cited, pp. 656-657.

|| Au. cit., p. 174

** Ditto, p. 182.

from the Miocene to the Siwaliks of India,—and most of them are in favour of the more recent period. Without entering into recondite theories of elevation here, I may point out that the whole of the Salt Range series, up to the top. of the nummulitic limestone at least, being conformable, and this series, together with the overlying tertiary beds up to the Siwalik group partaking of the general disturbance, the last elevation is shown to have taken place, or to have been going on subsequently to the upper tertiary period. The evidence afforded by the rocks is too uncertain to show whether this action was remittent or recurrent, but the varied nature of the whole series would suggest many changes of level.*

The subsidence alluded to by previous writers as necessary for the accumulation of several thousand feet of tertiary strata, would indicate a depression of far greater amount than the present total elevation of the range, and the break in the tertiary series, just above the local nummulitic limestone, alluded to by Mr. Medlicott,† might well be connected with some of the more recent oscillations.

So far as I can judge, the structure of the range leads to the inference that its existence is due to complicated lateral compression

* The Salt Range gives indications of the existence of land at no great distance, contemporaneously with the formation of several of its boulder beds, even so far back as the period of its earliest groups, and again at various stages up to tertiary times. In one case a section in supposed Triassic beds, between Pid and Kheura, exposed what seemed to be an old river course. The transported fragments in these boulder beds include very similar varieties of crystalline rocks irrespective of age, and amongst them rocks unknown to exist northward of the range. This suggests the idea that the land whence these fragments came may have been situated to the south. Other indications of contemporary land in that direction may be found in the fossil vegetation of the newer rocks as well as their remains of land animals.

† Records, Geol. Sur. Ind., Vol. IX, p. 55.

under unequal conditions of resistance, which in a late tertiary period developed itself in local disturbance along one or more lines of fissure coinciding with the direction of the uniclinal escarpments, the whole of the features having been subsequently much modified by meteoric erosion.

Relations between the form of the ground and its geological structure.

The strongly marked relations which often exist between the forms and structures of mountains are seldom more evident than in the Salt Range. In this case they result from much disparity of texture in the different strata, and they are most pronounced where the disturbance has been least violent.

Not alone are these relations observable in detail, but they affect the range generally, for its strata differ from those of the neighbouring lower country (where these can be seen), and the outcrops of many varieties of the rocks are indicated in the forms of the ground. Thus the *Kuddera* country of the northern slopes is always formed of soft sandstones with innumerable alternations of clay bands; the plateaux are chiefly composed of limestone, rarely overlaid by some beds of the succeeding group, and all the escarpments are formed of the hard limestone, of still harder dolomite or magnesian sandstone, or where this is absent, of massive or uniform beds presenting a relative contrast of texture to others in their vicinity.

Escarpments, &c.

The escarpments frequently exhibit three or more groups of different hardness, some of them producing under-cliffs, and many of the slopes both on the plateaux and along the unscarped mountain sides are derived directly from the bedding of the rocks.

Disintegration, south side of range.

On the south side of the range below the solid escarpment the fragmentary stratigraphical relations all but defy interpretation, the transition from continuity to

disruption being frequently impossible to trace. Limestone tracts are often found with a gentle slope in a peculiar semi-disintegrated state, the rock although not being *in situ* is yet unmixed with fragments of other rocks and retains sufficient of a former stratigraphical position to conceal the beds beneath. Outlying patches of such half-degraded rock may be sometimes seen in contact with, or resting upon, a lower group, to the exclusion of other intervening layers washed out from beneath.

In parts of this dislocated country as many as twenty chief lines of division may be traced, often between widely different and abnormally placed rock masses, and taking as many different directions within one square mile as there are lines; where such confusion prevails, the difficulty of distinguishing between faulting and land-slip sometimes becomes an impossibility. All this dislocation and disarrangement is generally referable to geological and stratigraphic structure, and especially to the occurrence of soft saline marl, gypsum and rock-salt beneath superincumbent masses of hard solid limestone, or other rock, having allowed the upper bed to sink into any accidental position of rest as the action of disintegration went on.

Atmospheric influences.

In the Upper Punjáb rains are scarce or inconstant, capricious or limited, in great measure, to hills of greater altitude and extent than the Salt Range; the climate of the country is marked by a large daily range of the thermometer; the seasons are extreme, and for most of the winter months the conditions of a desert prevail—intensely dry air and bright sun during the day, and excessive radiation of heat, causing frost, at night. Such atmospheric influences are most likely to operate strongly in altering the form of the ground, particularly where many of the rocks are absorptive or saline as in this district. Add to these the effects of the strong dry winds which prevail at certain seasons, and it will be readily understood, that with heavy rains succeeding intervals of drought, there are causes

in operation sufficient to account for a large amount of meteoric denudation.*

If anything were wanting to prove the extent of this erosive action, the rain-worn surfaces of the limestone plateaux, the numerous little patches of level ground, remains of former flats among the *Kudderas*, the pinnacles and profound ravines along the escarpments, and the mass of detritus brought down by torrents, would amply establish its existence and its power. To this agency alone, operating upon suitable materials, can I attribute the removal of the once overlying tertiary sandstones,

* The rainfall at the following stations near the Salt Range is taken from the Punjáb *Government Gazette* for three years :—

Name of Station	1869.			1870.			1871.		
	From April 1st to December 5th, 1869.	Average total from April 1st, 1864, to 5th December, 1869, 5 years.	Average annual fall.	From April 1st to December 2nd, 1870.	Average total, fall from April 1st, 1865, to December 22nd, 1870, 5 years.	Average annual fall.	From 1st April to December 21st, 1871.	Average total fall from April 1st, 1866, to December 21st, 1871, 5 years.	Average annual fall.
	In.	In.	In.	In.	In.	In.	In.	In.	In.
Jhelum, east of Range ...	5·1	10·9	13·8	17·9	21·0	21·9	10·1	13·0	21 9
Shahpúr, south of " ...	13·1	7·9	14·9	9·0	9·8	16·2	10·4	11·9	17·0
Chakowál, north of " ...	...	...	...	...	...	...	9·1	7·0	13·0
Tullagung, " " ...	...	...	...	...	...	...	7·8	7·4	13·3
Pind-Dádun-Khán, south of Range	...	...	...	...	...	...	9·8	11·0	14·6

From this it would appear that the general average rainfall of the country in which the Salt Range is situated is equal to about 16 inches. Mr. Login, in a paper which has recently appeared in Vol. XXVIII, Journal of the Geological Society of London, p. 186, thinks that the rainfall of the Punjáb is the same now as it was two thousand years ago, but more restricted to the mountains. Dr. Vérchere, at section 96 of his paper previously referred to, argues that at the beginning of the miocene period in these regions the rainfall was excessive, resembling that of Patagonia.

the cutting of the Indus* and other gorges, and the excavation of precipitous valleys over 1,000 feet depth.

Marine erosion.

It has been thought that the cliff feature, here so striking, resulted from marine erosion; of course this may have taken place, but so great has been the subaërial denudation, that the traces of marine action would now be sought in vain.

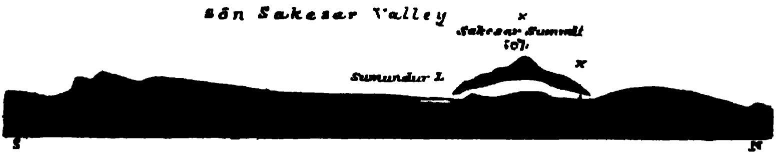

Fig. 3.—Profile of Sôn Sakesar basin. Natural scale ¼ inch=1 mile.
Sakesar Mountain, 6 miles to west.

Sôn Plateau lakes.

The salt lake basins of the Sôn valley present some peculiarity as to their excavation; the largest, the Samundar lake, at an altitude of 2,526 feet and with a catchment area of about 60 square miles, covers 6 square miles of surface, and varies in depth and area with the accession of rain water, but is usually shallow. It has no visible outlet, and the difference between the altitude of the lake and that of the lowest part of the edge of its basin may be less than 100 feet. The greater part of the basin is formed of limestone and is rocky, but in an easterly direction there are large deposits of coarse detrital materials that may conceal some spot where the water could have escaped, before the passage was blocked up by their accumulation. No sufficient reason for calling in the aid of ice to assist in

* If only a coincidence, it may be observed that the depth to which the last results of atmospheric erosion have reached at the water escape of the Indus from the hills, is nearly equal to the whole fall of that river from Kálábágh to the sea. The average of twenty heights on the Potwar plateau gives 1,426 feet, and the depth of the Indus gorge at Kálábágh, including that of the river itself, is about 650 feet, the fall from thence to the sea (taken from the height on the maps) being equal to 681 feet, or 32 feet less than half the average elevation of the Potwar country.

explaining the excavation exists, and though there may have been formerly subterranean passages through which dissolved portions of the limestone could be carried off, the saltness of the water indicates evaporation as the main cause to limit the area of the lake.

The Khabakí lake at 2,481 feet of elevation is in an even deeper, though much smaller, depression of the Sôn; like the Samundar, it has no outlet either. It is 276 feet lower than the nearer summit elevations, and from 114 to 196 feet lower than the least elevated part of the margin of its basin; this also appears to be more completely a rock basin than the other, and both, if filled, would discharge into one of the heads of the Narsingphoar ravine. Another and smaller lake is that of Jalar to the southward, also without an outlet. All are situated in limestone tracts, and though probably connected with "swallow holes" or the damming up of former water passages, the size and form of some of the basins render local subsidence not at all an improbable cause for their existence.

Under existing circumstances, and with nothing to carry away accumulating water except evaporation, these lakes must be gradually silting up.

CHAPTER III.

STRATIGRAPHIC GEOLOGY.

The Salt Range and the neighbouring parts of the Himalaya are as unlike in geological structure as adjacent regions containing several of the same formations need well be. The Khásia hills,* eleven to twelve hundred miles distant, occupy a somewhat analogous position with regard to the great chain, yet notwithstanding the distance, the geological section of that distant locality is not more dissimilar than that of the nearer known Himalayan regions described by Mr. Medlicott,† Dr. Stoliczka,‡ and others.§ From the Salt Range to the Khásia hills, the structure of the ground concealed by the Gangetic or other alluvium is quite unknown, and in other directions, towards the peninsula of India, so far as the country has undergone examination, its geology is equally different from that of the Salt Range, so that the latter becomes unique if its geological features do not extend westward and south-westward.

Disparity with Himalayan regions.

The disparity with the Himalaya consists not so much in the absence of formations common to both as in the relative character of those represented; the deposits of each possess petrographic and palæontological characters peculiarly their own, analogous to the distinctions marking the "Alpine" and "extra Alpine" regions of continental palæontologists.||

Some eight fossil species are mentioned by M. de Verneuil as common to the carboniferous series both of the Himalaya and the Panjáb,

* Mem. Geol. Survey, India, Vol. I.

† Ibid, Vol. III.

‡ Ibid, Vol. V.

§ Ibid, Vol. IX.

|| This analogy was first suggested by remarks of the late lamented Dr. Stoliczka made while examining a few of the Salt Range fossils I had collected, and the suggestion seemed borne out by Dr. Waagen's field examinations in the Upper Panjáb.

and these include some of the Salt Range forms,* but with this exception, Dr. Waagen's acquaintance with scattered Upper Punjáb Himalayan localities tended to show that the fossils of their formations, other than carboniferous, compared with the Salt Range, possessed facies as distinct as the petrological characters of the rocks which contained them.† The latter distinction, too, varies in degree, the rocks older than Nummulitic being least similar in each region; the nummulitics, though distinguishable, approximating, and the overlying tertiary sandstones and clays being most alike; indeed, they belong to the same great series,‡ in contact at either side with the inferior rocks of both regions.

Rock Groups.—For the sake of conveying a comprehensive view of the various groups and their distribution, I annex a diagram, Pl. IX, in which their lateral extensions are shown to scale, and give a short reference to each before describing them more fully. They are naturally divisible into groups, thus:—

No. 1.—The lowest is the gypseous red salt marl with rock-salt.

No. 2.—The group which succeeds is less constant than the last, but its massive purple sandstones are prominently seen in the southern sections.

No. 3.—Overlying No. 2 is a zone of softer nature and darker colour, black to dark gray argillaceous beds, with harder bands. It divides and dies out to the westward, and it contains the oldest fossils met with—Silurian.

* Since the above was written, a specimen of *Productus Humboldtii*, D'Orb., has been found erratic at the northern base of some hills south of and close to Hassan Abdal by Mr. R. Lydekker. This is a Salt Range species, and may indicate the occurrence of a representative of the Salt Range carboniferous group among the outer Himalayan hills much nearer than the great ranges of the Himalaya beyond the Kashmir valley. How far the similarity of the group to the Salt Range carboniferous may extend, remains to be discovered.

† The difference between the nummulitic fossils of the Sub-Himalyas (Sabáthu) and the Salt Range was long since pointed out by D'Archiac and Haime, and mentioned in Mr. Medlicott's Sub-Himalayan Memoir.

‡ Southward, in Kach and Lower Sind, the marine tertiary beds, newer than the nummulitic, are entirely different from these.—Mem. Geol. Surv. Ind., Vol IX, pt. 1

No. 4.—The last group is closely succeeded by a strong and frequently much harder zone, characterised to the east by hard magnesian and other light-coloured sandstones with beds of dolomite. It also dies out westward. The continuation of the succession above this group differs in different parts of the range.

No. 5.—Near where No. 4 becomes divided and no longer traceable as a connected group, its beds are succeeded by a softer and coarser set of granular, strongly bedded, sandstones, surmounted by pale lavender-coloured clay.

No. 6.—Resting immediately on the last is a group of limestones chiefly crowded with carboniferous fossils, and only developed at the western side of the range.

No. 7.—So intimately united with the preceding as to appear to form a conformable upper portion is another group of limestones, sandstones and shales or clays, in which fossils are numerous. It is not quite so extensive laterally as No. 6, and between these lies the boundary separating the palæozoic and mesozoic rocks, this upper group being of Triassic age.—(Waagen.)

No. 8.—To carry on the succession we must again turn to the eastern part of the range which groups 6 and 7 do not reach. Here, resting upon No. 4 and disappearing near the commencement of No. 5, is a group of thin, flaggy sandstones interstratified with blood-red clays, which, from its general relations to the rocks above, has been considered to occupy nearly the same place as the distant westerly group No. 7, both being probably Triassic, though this can only be decidedly stated for the former.

No. 9.—The next group lies in the far west of the range succeeding No. 7. It contains white, red, and soft sandstones,

with yellowish and gray limestones, and yellow marls. Its fossils are numerous and of Jurassic age.

No. 10.—Newer than the last, but never in contact with it, is a zone of soft, greenish brown, and olive sandstones, conglomerates, and dark shales. It commences in the eastern part of the range, extending further west than No. 8 or any of the underlying groups to the east; fossils are most rare and ill-preserved, but such as were found were considered by Dr. Waagen probably cretaceous.

No. 11 group is the massive white or light-coloured nummulitic limestone forming so marked a series of cliffs and escarpments, and of which the summit of the range consists. It disappears in the dislocations at the Indus and also thins out to the east.

Nos. 12, 13, and 14 include the portions of the tertiary sandstone and clay series overlying the nummulitic limestone. Three sub-divisions of it, including Nahan and Siwálik beds, have been recognised, chiefly in the east part of the district, by Mr. Medlicott.

No. 15.—In this may be included the alluvial and other superficial deposits, together with an older diluvial or post-tertiary conglomeratic group.

The presence of a few small exposures of a peculiar trappean rock will be noticed in another place.

From this and Plate IX, it will appear that the rock groups are irregularly distributed laterally. Of the whole (excluding the more recent), seven are found to the east and seven or eight to the west, two only, or at most three, being continuous throughout the range. Four of the western groups are absent in eastern sections, and four belonging to the latter are unrepresented in the west, while of these eight only two may belong to the same period.

The sub-divisions as indicated all possess sufficiently well-marked petrographic characteristics to enable them to be distinguished. If some hesitation on this ground might be felt, as to the boundary between Nos. 6 and 7, it would be removed by palæontological evidence. The fact of superposition establishes several of the groups, but some, though probably related, are so distant from each other that this clue to their place is absent, and when fossils are entirely wanting, as in Nos. 1, 2, 4, 5, and 8, their geological age becomes less certain, though their places in the series may give some aid as to their approximate position.

Fossiliferous beds.

Of the older groups, No. 3 only has yielded fossils and at but two places, where several small shells of the genus *Obolus,** Eichw., or *Siphonotreta*, Vern., were found by myself and determined by Dr. Stoliczka,† thus indicating an age not newer than Silurian.

In group No. 4, obscure Fucoidal impressions have been met with, but nothing determinable. Group No. 6 abounds with well-known carboniferous species and many new ones according to Dr. Waagen. No. 7 contains quantities of *Gastropoda* and bivalves of Triassic age, (and some which Dr. Waagen thought might possibly show the lower beds to belong to the continental Dyas). No. 9 has numerous *Belemnites* and other jurassic fossils as recognised by Dr. Waagen and previous observers. No. 10 has furnished but scanty and obscure palæontological evidence, while No. 11 is full of ill-preserved nummulitic fossils, and the tertiary sandstones, &c., above frequently contain mammalian bones, crocodilian and other remains.

Carboniferous *Ammonites.*

Perhaps the most remarkable fact relating to the fossils found in the Salt Range is the discovery of true *Ammonites* in the carboniferous rocks near Jabí, collected by Dr. Waagen himself (See Mem. Geol. Surv. India, Vol. IX, pt. 2). It

* See remarks on *Obolus*, with plates, by T. Davidson, Esq., F. G. S. &c., "On earliest forms of *Brachiopoda* hitherto discovered in the British Palæozoic rocks."—Geol. Mag., Vol. V, p. 303.

† Dr. Waagen has seen these fossils *in situ* and cleared some specimens for further determination, but did not decide to which of the two genera they belonged, so far as I am aware.

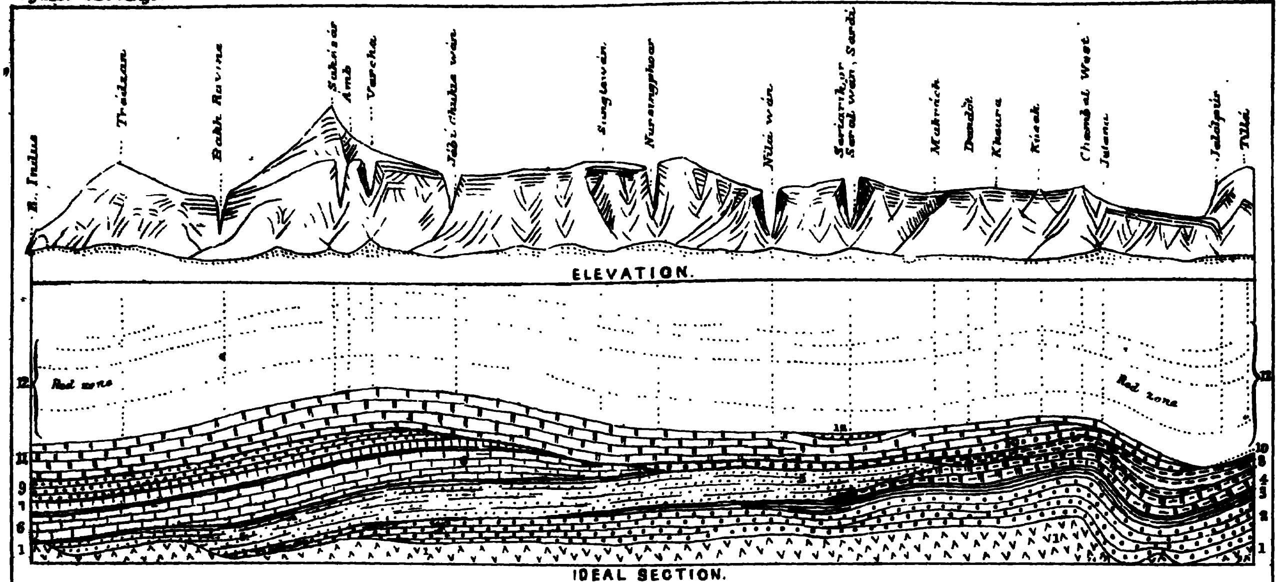

Diagram to show the distribution of the Salt Range Series (Note. The inclinations are not those of dip) Distance represented = 120 miles English.

1 Salt Marl. 2 Purple Sandstone. 3 Obolus or Syphonotreta Zone. 4 Magnesian Sandstone. 5 Speckled Sandstone. 6 Carboniferous or Lower Limestone. 7 Ceratite beds.

8 Salt Crystal Zone. 9 Variegated Group (Jurassic) 10 Olive Series (Cretaceous) 11 Nummulitic limestone (Eocene) 12 Sub-Himalayan.

The distances being so much contracted the formations assume angles resembling but not always truly those of disturbed bedding.

is greatly to be regretted that his examination of the Salt Range collections, so unfortunately interrupted by his illness, was left incomplete.*

Observe.—In this and following tables the rocks are arranged in natural order, lowest beneath and newest at top, as printed :—

Salt Range Series.

			Feet.
		QUARTERNARY.	
Alluvial and sub-recent. Post Tertiary.	15 Rain-wash, alluvium, and superficial deposits.		
	Pebble beds ...	Conglomerates ...	... various thickness.
		CAINOZOIC.	
Pliocene ?	14. Upper Siwalik	Conglomerates, drab and pink clays ...	800 to 2,000
Miocene	13. Lower Siwalik ..	Gray sandstones and red clays, with Bones	1,200 to 7,500
	12. Nahan .	Greenish-gray sandstones crocodilian remains and fossil wood ...	600 to 1,000
Eocene	11 "Upper limestone" of Salt Range.	Nummulite limestone &c., large Gastropods, Bivalves, Echinoderms, &c.	400 to 600
		MESOZOIC.	
Cretaceous	10. Olive series ...	Olive, reddish, and white sandstones, calcareous beds, black shales with boulders, *Terebratulæ* and Bivalves	150 to 350
Jurassic ...	9. Variegated group	Red and white and variegated sandstones, yellow and gray limestones and marls, some hæmatitic layers, *Ammonites? Belemnites*, &c. .	200 to 500
Trias ...	8. Pseudomorphic salt-crystal zone.	Red and lighter-coloured flaggy sandstones and blood-red clays or shales, pseudomorphic salt-crystals	50 to 500
	7. Ceratite beds ..	Gray limestones, calcareous sandstones and gray marls weathering greenish, *Ceratites*, &c.	120 to 250
		PALÆOZOIC.	
Carboniferous.	6. "Lower limestone" of Salt Range.	Gray and magnesian limestone, calcareous sandstone and argillaceous beds, numerous *Productæ*, *Spiriferæ*, *Bellerophon*, *Goniatites*, and many other fossils	800 to 500
?	5. Speckled sandstone	Speckled, reddish and white sandstone, red and lavender clay . .	250 to 450
?	4. Magnesian sandstone.	Light-coloured magnesian sandstone, dolomite-sandstone, and shales ...	150 to 250
Silurian ...	3. *Obolus* or *Siphonotreta* beds.	Black shales with glauconitic calcareous layers and sandy bands, *Obolus* or *Siphonotreta* ...	20 to 150
?	2. Purple sandstone..	Deep purple sandstones	250 to 450
Eruptive ...	Diorite ? and Ash	A few exposures connected with the salt marl close up to base of No. 2	lenticular.
?	1. Saline Series ...	Bright scarlet gypseous marls with thick beds of rock-salt, gypsum, thin dolomitic layers ...	800 to 1,500 Total unknown.

* The whole of the collections from the palæozoic and mesozoic formations of the Salt Range have lately been sent to Dr. Waagen for description in the Palæontologia Indica.

Conformity.

The whole of this great series, from the red marl up to the post-tertiary group, presents a general and regularly successive parallelism of stratification, each group succeeding the one it rests upon without the intervention of any marked traces of erosive action.* In a few isolated cases the upper surface of the highest carboniferous layers has been found locally rugged, as if the upward succession were less regular at that horizon, but in its general aspect it presents no exception to the rule.†

Hæmatitic layers have been observed in some instances to mark the junction of some of the upper formations, both where the succession indicates the greatest irregularity and where it exhibits the least.

One break, indicated by derived pebbles of the lower rocks, at the junction of the tertiary sandstones with the nummulitic limestone, accompanied by as much parallelism as elsewhere, will be noticed further on.

Saline Series.

Red Marl: Gypsum: Rock-salt.

Salt Marl No. 1.

The saline series is distinguished by the predominance of marl, in colour bright scarlet to dull purple, containing the rock-salt, gypsum, and some subordinate dolomitic layers, all forming together the lowest member of the series. In every section and every glen where the section is seen, the gypseous marl may be clearly observed passing beneath the next group and underlying all. It is always succeeded by dull earthy sandstones or conglomeratic beds, and always presents the same peculiar aspect.

* In the outer Himalayas, at Sirban mountain, near Abbottabad, there is marked unconformity of the Trias, &c., resting upon the supposed Silurian slates.

† This unbroken passage of the rocks from Palæozoic to Mesozoic formations, the distinction being chiefly marked by the fossils alone, seems also to characterise the succession in the Himalayas as shown by Dr. Stoliczka's Sections and his papers,—see Mem. Geol. Surv. Vol. V.

Colour.

Its brilliant scarlet colour, together with the arid aspect of the ground it forms, distinguish this rock from all the other groups. Under vertical sunshine it pales considerably, owing to the slope of the ground, and to the associated whiter gypsum being more visible; but when the sun is low the marl glows vividly in the slanting rays, reflections of one surface upon another producing the softest and most velvet-like transparent shadows, while parts of a dull purple colour vary its monotony, and, at a sufficient distance to be influenced by the blue of the atmosphere, this gives rise to many harmonious effects.

The marl forms the most noticeable portion of the saline group, but in close association with it are thick beds of gypsum and thicker ones of rock-salt. It is tough rather than hard, but when very dry, possesses much the consistence of sun-dried brick.

Composition.

According to Dr. Warth's examination, it contains a quantity of gypsum, and from Dr. Fleming's account I extract the following: "It does not disintegrate when treated with hydrochloric acid, but in powder effervesces strongly, the greater part remaining undissolved as a red mud composed of clay and sulphate of lime; the portion soluble in acid consists of carbonate of lime and carbonate of magnesia in about equal proportions with a little alumina and peroxide of iron, to which it owes its colour."* With this composition the name of "gypseous marl" is not inapplicable.

Stratification and thickness.

Beyond the gypseous, saline, and dolomitic layers the red marl bears few original traces of stratification, or inter-stratification, generally none at all; hence it is difficult to form any correct idea of its thickness. Supposing it to have, where most largely developed, the same nearly horizontal stratification as other groups in its vicinity, and reckoning from the height of the mountain slopes which it forms (near Kúsuk), it would appear to be at least 1,500 feet in thickness. It may be doubted whether another example could be

* Fleming's 2nd Report, p. 240.

found of such a homogeneous, argillaceous and aqueous deposit of the same depth in which signs of stratification are equally absent. In strong contrast to this is the perfect lamination frequently seen in the enclosed salt, and in the platy dolomitic layers. From the contorted state of the latter, and the curvature of the beds of salt in some of the mines, it may be presumed that, whether stratified or not, the salt marl is likewise disturbed. It has never been found to show any traces of erosion before the deposition of the next group.

Dr. Fleming speaks of parts of the marl as brecciated, enclosing angular masses of other rocks, and mentions thin argillaceous, dark-red layers in it. The latter I have not been able to detect, and the former observation seems to refer to some superficial mingling of fallen materials. Every one who has examined the ground pronounces the marl unfossiliferous, but I am not aware that any of it has been subjected to microscopic examination.

It may be found in the most complex association with various other groups, and through faulting it is brought into juxta-position with some of the very newest rocks of the series, or it may be apparently inconsecutively overlaid by various bands—a result of progressive displacement, in most cases caused by the dissolving of the salt or washing out of the marl from below the superior groups. It thus continually makes its appearance among the stratigraphic wreck which it has itself produced, and it is not completely buried by the mass of the overlying series, fractures permitting it to appear occasionally on the top of the range and along its northern slopes. Along the southern foot of the range it is seen wherever the ground is not thickly covered by debris. It rises pretty high to the eastward; at Khewra to 1,000 feet nearly; at Kúsuk to between this and 1,500; at Mount Chambal (west) to nearer 200 feet; but westward of Makrách it lies generally low. At Varcha it is again high; it has been found at Dheri in the plateau country close to an elevation of 2,739 feet, and is

Distribution.

forms a hill of some 427 feet* above the plains at Mári on the Indus. On the north side of the range it is found in a small glen at Vasnál, and obliquely traversing the slope from Kalar Kahár lake to west-by-south.

Minerals.

The only non-constituent minerals which the marl is known to contain besides the gypseous and saline ones are bi-pyramidal quartz crystals in the gypsum of Mári (said also to be found at Sardi), scattered crystals or nests of iron pyrites in the gypsum also, here and there, and earth-oil intercalated with the gypsum of Khewra gorge.

Age

As to age, the salt marl has been referred to Triassic, New Red Sandstone or Permian, Miocene or Pliocene, but it is now known, from the way in which it passes beneath the overlying beds, to be not newer than Silurian—a fact depending upon the discovery of *Obolus* or *Siphonotreta* in the group No. 4. Beyond this its place cannot be as yet more definitely fixed.

Gypsum.

Besides the disseminated gypsum, the red marl contains extensive beds and masses of this mineral, often largely developed in its upper part, but also more doubtfully present in lower situations. As a rule, the gypsum overlies the salt. Sometimes it is interstratified with the marl, and sometimes it appears as if former beds had been broken up, or partially dissolved, leaving large fragmentary masses embedded in the softer rock. Contorted or even distorted lines of stratification are found in the gypsum, but it has never been found to contain any detrital pebbles or foreign fragments. According to Dr. Fleming, it is nearly pure sulphate of lime, free from carbonate of lime. Its texture varies from compact and sub-crystalline to saccharine, and plates of clear selenite are also found. Its colour is white, or white mottled with grey or bluish grey, or it is sometimes pink or red; the more compact varieties are used for turning into ornamental utensils.

* From comparison of heights on map and that given by Fleming, p. 449, 2nd Report.

Semi-anhydrite.

Although the gypsum occurs in great quantity, true anhydrite has never been found associated with it or in the marl, the nearest approach to this mineral being certain large nodular cores of greater weight and hardness and of a bluish white tint within beds of the whitish gypsum. Specimens of this rock were found by Dr. Warth to contain only 5 per cent. of water.

Bischof says: Sulphate of lime at high temperatures under pressure crystallises with 6·21 per cent. of water, thus forming a semi-anhydrite* (anhydrite being of course waterless and gypsum containing 20·79† per cent.), and coming close to the Salt Range rock. Gypsum (according to Bischof also) may have three-fourths of its water driven off by long ex-posure to boiling temperature, leaving the same percentage nearly as in Dr. Warth's specimen. Hence it would appear that if this be an original rock, a high temperature may have existed during its formation,‡ or heat may have acted upon it since its deposition. If neither be the case, the situation of this semi-anhydrite may suggest the transition of the rock from anhydrite to gypsum by taking up water. This variety melts away or changes into finely crystalline white powder below the surface of a stream highly charged with salt in Khewra gorge.

Dolomite layers in gypsum.

Sometimes in thick masses of the ordinary gypsum, there occur layers of white, brittle, hard flaggy dolomite which looks and burns like a limestone. At one or two places, notably at the southern foot of Mount Tilla,§ these dolomite layers contain numerous and very perfect casts of large "hopper-shaped" crystals of salt. The same kind of rock becomes massive at the western foot of Mount Chambal (east) northward of Jalálpúr, also in Khewra glen, where a fœtid variety is associated with the peculiar eruptive rock of

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* Bischof on rock-salt works near Stassfurt, C. E. M. Pfeffer, Halle, p. 48.

† 20·88, *Vide* Page, and 20·8, Dana.

‡ The gypsum of the Spiti Valley is attributed partly to thermal springs.—Mallet, Mem. Geol, Surv. Ind., Vol. V, p 159.

§ First observed by Dr. Warth.

the locality and with coaly-looking highly bituminous shales occurring as a pocket or small lenticular mass.*

In several places, and apparently low down in the salt marl, hard, thin, dark, platy, gray, or greenish layers of what appears to be also a sandy dolomite with shaly partings, have been met with in several places: they may perhaps be the thin beds of chert and silicious sinter of Dr. Fleming's paper (p. 240).

In a few spots—fewer even have been placed on record by others—

Trap.

I have met with some irregular patches of a dark purple compact to earthy volcanic-looking rock. It occurs associated with gypsum and red marl close to the upper surface of the saline series, just below the purple sandstone (No. 2). It has the appearance of a diorite, and is associated with paler purple volcanic tufa or ash. It is crowded with stellate accicular crystals of what may be decomposed actinolite,† and contains strings and nests of talc, small geodes of reddish and clear quartz and chalcedony, minute cavities filled with reddish calcite, strings of quartz and white specks of some decomposed mineral not sufficiently abundant for determination. I have not observed this trap in dykes, but in nearly horizontal lenticular layers from a few inches up to 6 feet thick or even more; in some places between gypsum bands, sometimes having a thin layer of the red marl between it and the overlying sandstone, or, as in the Nílawán ravine, lying between rock-salt and gypsum. Here it is partly decomposed, but may have been 15 feet thick. The associated violet or lavender earthy portion is used by the natives instead of soap.‡ It generally overlies the more solid rock with an irregular thickness up to 4 feet. Mr. Theobald seems to have found this rock in a more dyke-like position altering the adjacent rocks—an

* Some of the shale made a fine blazing fire, decrepitating while burning and leaving much ash, also giving off sulphurous fumes. From this rock Dr. Warth obtained a dark mineral oil by distillation.

† Tremolite: Fleming, p. 242, and Theobald, p. 676.

‡ Not unlike the ashy clays with the volcanic-looking infra-nummulitic laterites in Kachh.—Mem. Geol. Sur., Vol. XI.

observation difficult to make on account of the general decomposition in its vicinity where I have seen it. In the Upper Khewra gorge the following section occurs :—

8. Purple sandstone	...	...	... 0 to 0	feet.
7. Red gypseous clay	...	...	... 10 to 15	„
6. Lenticular mass of trap, maximum ..			... 5 to 6	„
5. Greenish clay	...	...	... [illegible]	„
4. Powdery dolomitic layer, white		...	... 4	„
3. Bituminous shale	...	...	... 6	inches.
2. Dolomitic laminated bands		...	... 15	feet.
1. Red marl, gypsum, and salt		...	... 1,000	„

Salt.

The rock-salt is found near the upper part of the red marl as a rule, and generally just below the greatest development of the gypsum, with which its stratification is parallel. It alternates with thick, dark-brownish red beds of impure saline marl, called by the natives *kallar*, and is pink, reddish, or white, rarely having gray blotches, but frequently showing numerous alternations of laminæ of small thickness, reddish and white colour and different degrees of opacity.

The marl, gypsum, and salt, all yielding rapidly to the wasting action of the atmosphere, which reduces the whole to a state of obscurity, it is difficult to find any natural sections from which to gather the detailed structure of the saline zone. In Khewra mining region, where a portion of the saline deposits has been most fully explored and a survey of the mines made, the lowest bed of the series as known there is a bed of salt, but this is insufficient to show that salt-rock is always the lowest member of the series.

Continuity.

The various modes of concealment, natural or artificial (to prevent theft), combine to prevent an idea being formed of the lateral extension of the salt beyond what may be gathered from its very frequent occurrence along the southern foot of the range. As to its thickness, whether local or otherwise, the great caverns excavated in it at Khewra, Varcha, and other localities (some of which are large enough to contain good-sized parish churches or large houses) give a general notion of the massive character of the deposit.

At the Mayo Mines, Dr. Warth* has found from his survey that the salt occurs in five great beds having a united thickness of 275 feet, alternating with another 275 feet of *kallar* or impure salt, the whole of this saline group being intercalated in the upper part of about 1,000 feet of red marl and gypsum.

Single beds of the salt are over 100 feet in thickness here, and in other parts of the range vary from 6 to 30 feet; indeed, the salt occurs so frequently that it does not appear to have ever been necessary to trace out the extension of any particular bed.

Purity.

The beds are not all of equally good salt, some containing a little earthy matter, but many, if not the majority of them, consist of the mineral in a fine translucent or even transparent condition varying from crystalline to compact.

Composition.

The following analyses of the salt of the (Khewra) Mayo Mines will be found with others in Dr. Warth's Report already mentioned, these having been made by Mr. Cornelius Hickey, Chemical Analyst, Agra† :—

Contents.	I.	II.	III.	IV.	V. Average
Earthy matter	Trace.	Trace.	Trace	0·04	Trace.
Sulphate of lime	0·77	0 69	0·92	0·68	0·75
Chloride of calcium	..	0·42	1 16	. .	0·50
Chloride of magnesium	0·71	0·71	1·34	2·22	1·25
Chloride of sodium	94·60	92·84	92·80	91·74	93·00
Water and loss	3·92	5·34	3·78	5·32	4·50
Total ..	100·00	100 00	100·00	100·00	100·00

No. I. Purest white crystalline salt.
No. II. White salt as sold from depôt, Buggy Mine.
No. III. Red salt as sold from depôt, Stjewal Mine.
No. IV. Mixed red and white salt as sold from depôt, Buggy Mine.
No. V. Average good salt of Mayo Mines calculated from the others.

* Report in Appendix to Administration Report, Inland Customs, 1869-70.

† Dr. Fleming thought the salt contained no chloride of magnesium, and that the red salt derived its colour from something of an organic nature (p. 243, Report previously quoted) Dr. Jameson (auth. cit.) speaks of crystals of quartz as occurring, though rarely, in the salt. These I have never observed or known to be observed.

Structure

The banded structure of the salt beds is chiefly caused by layers of different colour, the bands being most solid, looking or of darkest colour about the middle and softened into a paler tint on the edge; sometimes there are alternating layers of a red earthy nature from which Epsom salt effloresces. The strata have a regularity intermediate between that ordinarily observable in flag-stone and sandstone, the bands or layers having in some places for considerable distances vertical to their planes a general thickness of 6 to 8 inches varying to 2 feet, while for several yards across the strike in some of the larger beds no lamination at all is to be seen. There are also numerous irregularities of the bedding showing much lenticular arrangement of deposition. In one place an earthy film was observed crossing a thick bed in a zig-zag manner as if a crack had been filled up. No sign of current (ripple) mark or well-developed oblique lamination could be found. Layers of the salt thinning out, convex above and below, were frequently seen.

A contorted band of salt between two layers of *kallar* similarly curved was observed in the 10-feet marl bed (fig. 5), the appearance being precisely similar to that produced by disturbance in ordinary stratified rocks, though the arch was only about 2 feet across. One of the uppermost layers of the salt in the Khewra gorge has a mechanical brecciated structure, and encloses fragments of marl, gypsum, and of rock-salt.

Fig. 5.—Contortion in beds within the Mayo salt mines.

The whole of the group of salt beds at this place is shown to be curved by the different angles of dip observable, but none of the complicated little foldings so common in the adjacent gypsum and

dolomitic layers are apparent. The curvature might either result from general disturbance of the whole strata, or from partial motion in the saline series only, and would go to prove a certain flexibility even in the crystalline salt rock, which must have crystallised in horizontal planes originally. Superincumbent pressure is of enormous force in the mines, the strongest stone masonry, even in arches, being crushed out of form, and where large 40 feet pillars of salt are left to support the roof, this vertical pressure causes huge flakes of the mineral to separate.

At the ends of "drifts" also the pressure causes large pieces to flake off the vertical surfaces left unsupported by working out.

The whole mass of the salt-mines hill is subject to percolation of small quantities of rain water, which would eventually cause movement and slippage under the pressure alluded to.

The compact solidity of the salt may be inferred from the fact that sounds travelling through it are audible at distances of 110 to 130 feet (as proved by Dr. Warth's measurement). The miners often, in approaching drifts, signal to each other by blows of a sledge on the face into which they are cutting.

Associated salts.

Sulphate of magnesium (Epsom salts) is mentioned in small quantities in some of the analyses (given by Dr. Warth) made from waste-salt; its existence is doubtful, except to a very trifling extent in the mass of this rock-salt, but it impregnates the *kallar* and thin layers between the salt-beds. It also effloresces from the surfaces of the red marl in old workings.

Dr. Warth has also found in the mines a white mineral composed of gypsum, chloride of sodium, and sulphate of magnesium, besides most beautiful, long, curving, fibrous, spun-glass-like crystallisations of [illegible]

in some of the old drifts, which are now neither safe nor easy of access. In fissures of the salt* he has met with scattered crystals of selenite and crystalline nests of a mineral with the composition of Glauberite (sulphate of calcium and sulphate of sodium without water).

Potassium salts.

While a collection of the Salt Range minerals was being made for the Vienna Exhibition of 1873, a greenish or reddish-white glassy mineral, harder than common salt, was found by Dr. Warth extensively mixed with the material of the *kallar* band, separating the Sújewal and Purwálla salt seams of the Mayo mines. It predominated throughout a thickness of 6 feet in the *kallar* bed, and was largely mixed with sulphate of magnesium, which also prevailed through 7 feet of the same band immediately beneath. On a rough examination by Dr. Warth this was found to be potassium salt. In composition it varied, and two of the specimens for the Vienna Exhibition examined by Mr. Tween gave the following results:—

	No. 1. Colourless salt.	No. 2. Pink-coloured salt.
Chloride of potassium	3·8	61·43
Do. of sodium	...	29·32
Sulphate of magnesium	58·02	7·78
Do. of potassium	38	...
Water	·62	2·1
	100·44	100·63

This potassium salt is referred to in a translation from the *Jahrbuch der k. k. Geologischen Reichsanstalt*, xxiii, No. 2, p. 136,† as a white or reddish granular mixture of sylvine (chloride of potassium) and kieserite (sulphate of magnesium), the kieserite possessing the same hardness and cleavage as the Hallstadt mineral and also appearing to be compact. It

* In Sújewal and Purwalla mines, where the salt crystals sometimes assume unusual forms, the margins of the cube-faces being replaced so that the solid angles have 6 bevelled edges.

† Records, Geol. Surv. Ind., Vol. VII, p. 64.

has been ascertained that this potash salt forms only a local lenticular deposit: it has not been found except in this instance, so far as I am aware.

Size and quantity.

As to size and quantity, the salt deposits of this district rank high among known localities for the mineral, numerous though these are known to be.* The salt group of the Salt Range, though occupying a much greater longitudinal extent of country, displays much less salt at the surface than is exposed in the Trans-Indus salt region. The mineral is found at not very distant intervals along the south side of the range for a distance of 120 miles.

How much of the salt formerly existing has been removed by the percolation of fresh water, and perhaps subterraneously distributed to the southward, cannot of course be known, but it is on record that the water of the Thull or Bár and of many places in that direction is brackish or sufficiently saline for salt to be manufactured from it; this is at great distances from the Salt Range.

It is not easy to attempt even a rough estimate of the quantity of salt in the Salt Range. If an average thickness of only 135 feet and a width of three miles be assigned to the salt beds, then, in the 130 miles along which these are seen, there may be 130 miles × 3 miles × 135 feet of beds, giving as the solid content of the salt deposits nearly 10 cubic miles.

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* Large deposits of salt are known to occur at Hormus in the Persian Gulf, near the shores of the Caspian Sea, in Persia, in Algeria, in Europe, and America; but still those of the Salt Range seem hardly inferior to any of those recorded by Dr. Karsten (*Lehrbuch der Salinenkunde, Berlin*). Salt is not known to occur in the valley of Kashmir,—see Dana's Mineralogy, Art. Salt.

A shaft which took several years to sink is stated to have passed through 3,907 feet of rock-salt at Sperenberg, twenty miles from Berlin, without reaching the limit of the deposit (Sitzunsber d. Naturf. Gesellsch. zu Halle, 1867, 23 Nov.) The salt was met with at 280 feet from the surface of the ground, but the dip not being given, the thickness cannot be estimated. A measured section at Bahadúr Kheyl, trans-Indus, gave a thickness of 1,000 to 1,200 feet of salt, the very magnitude of which rendered it doubtful whether there were not concealed faults,

Origin of the rock-salt.

Rock-salt, gypsum, and dolomite have always presented, as to their origin, difficulties too well known to need recapitulation.* With regard to their occurrence in this district, notwithstanding the progress of geological knowledge, I may quote and apply this passage of Macculloch, written forty-six years ago: "It is far easier to show that the most simple and obvious hypothesis is wrong or imperfect than to propose a probable one;" and, further, I might almost use his words, "no rational explanation has yet been suggested, and I have none to offer."†

Though the subject still remains very much in the obscurity which surrounded it when that author wrote, a few points bearing upon it may be noticed.

Continuance or recurrence of the salt-producing conditions.

That the mysterious conditions necessary to the production of these deposits have been persistent from very early geological time, or else recurrent, is established by the local relations, the red marl and gypsum usually (but not always) accompanying rock-salt being as prominent in this region as in many more modern ones; while the saline nature of many of the groups would indicate the presence, more or less, of salt-producing conditions, from the silurian or pre-silurian epoch up to tertiary times.

Most, if not all, of the groups in the Salt Range series appear to have been marine, and saline ingredients of one kind or another effloresce from many of their beds, but as the succession is consecutive, or unbroken up to the base of the tertiary sandstone group, these saline traces do not appear connected with any derivative formation of the newer from the waste of the older rocks.

* It is the less necessary to discuss these causes here, because a similar subject has been noticed recently in describing the Trans-Indus Salt Region: Mem. Geol. Surv. Ind., Vol. XI, p. 87.

† A System of Geology, by John Macculloch, M.D., F.R.S., Lond., Vol. II, p. [illegible], Longman, &c; 1831.

Solar evaporation.

The regularity with which the red marl, salt, and gypsum are overlaid by aqueous deposits, together with their internal stratification, so far as this is exhibited, are in favour of the salt having been produced by evaporation, the theory most generally adopted.

Distance from any volcanic sources.

The absence in this vicinity of any known great volcanic vents, either active or dormant, at the early period to which the salt and gypsum belong, is not in favour of a strong connection with volcanic causes, and yet the idea is strangely associated with the fact that the only igneous rock of the whole Salt Range—one of apparently volcanic origin—occurs absolutely within the saline series. The suggestion of high temperature indicated by the semi-anhydrite, found not far from that porphyritic rock, bears upon this point, as does also the association of dolerites and trachytes with the salt-rocks of Hormuz in the Persian Gulf.*

Possibly limited area of accumulation.

The internal structure of the salt beds and the numerous indications of lenticular deposition, suggest limited areas of local accumulation on the same horizon; perhaps of similar character to the salt-lakes Professor Ramsay has supposed to have existed during the Triassic period.†

Some modern writers‡ suggest the existence of enormous salt-producing causes, at extremely remote geological periods. This silurian or pre-silurian Salt-Range salt being among the most ancient deposits of the mineral known, some trace of these causes of production might be expected to show itself, but nothing has been detected to indicate a different origin from other salt-rock deposits. On the other hand, the Trans-Indus salt, so much more recent, if laterally less extensive, has also

* Mr. Blanford's paper in the Records of the Geological Survey of India, Vol. V, part 2, p. [illegible].

† Anniversary Address, 1864, Quar. Journ. Geol. Soc. Lond., Vol. XX, p. 47; also Quar. Journ. Geol. Soc. Lond., Vol. XXVIII, p. 169.

‡ See Chemistry of the Primeval Earth, and subsequent correspondence by Dr. Sterry Hunt and Mr. David Forbes, Geol. Mag., Vol. IV, pp. [illegible] and Vol. V.

a much greater development in mass; and while the tertiary period to which it is believed to belong approximates to present time, this salt itself has a much greater structural similarity to the ancient deposits associated, like it, with gypsum, than to any known modern salt formation.*

Absence of organisms.

Recent salt regions are proverbially azoic, and no organisms of any kind have been found in this salt or the accompanying gypsum, nor yet any recognisable ones in the succeeding group; but burrows of Annelides (?) and small shells of one genus of mollusca occur in the next newer zone. However, if the salt were supposed to have been formed by the dessication of pools, there seems no reason why organisms might not be found in the saline series. Fossil bones occur in the gypsum of the Paris basin; and in the salt of the Ran of Kach, fish, water-snakes and insects, prevented by the brine from undergoing decomposition, may also be seen. Doubtless the remains of these would become preserved in the adjacent mud of the Ran.

Quantity of sea-water necessary.

The enormous quantity of sea-water necessary for the formation of so much salt† and the absence of ordinary detrital stratified deposits formed in that sea are also revalent considerations under the supposition of evaporation.

Purple Sandstone.

Position.

No. 2.—The *Purple Sandstone* next above the *Saline series* possesses great uniformity of aspect and texture except in the far western part of the range. Its lower

* For information regarding modern Indian salt formations, among other sources, see 'Ran of Kach, Trotter; Appendix to Annl. Rept., Gt. Trig. Surv., 1872-73; Kach, Mem. Geol. Surv. Ind., Vol. IX, pt. 1—"Sambur Lake;" Rept. Admin. Inland Customs Ind., 1870-71, pp. 112—125; Panchpadder Salt Works, Burnes, Journ. As. Soc. Beng., Vol. II, p. 365—"The valley of the Poorna River." Records Geol. Surv. Ind. Vol. II, pt. 1.

Salt is stated to occur in the Hindu Kush Mountains, but whether recent or not I could not discover from my native informant, the only person who had seen it to my knowledge.

† For every cubic foot of salt, it may be taken that 50 cubic feet of sea-water would have to be evaporated, or for a column of salt of 275 feet (*ante*) by 1 foot square, a depth of more than 2¼ miles of sea-water should disappear, not to mention the quantity of salt in the impure *Kallar* beds adjoining to form the 550 feet of salt rocks at the Mayo mines.

fifty to one hundred feet immediately succeeding the red salt marl are very earthy, but of the usual purple colour, and appear like a transition from the marl up into the sandstone; the latter is generally soft and splintery below, where the lines of bedding are not very clearly marked. Above the earthy portion argillaceous inter-stratifications are rare or absent, and the beds are all of a nearly equal hardness, considerably less than that which is usual in palæozoic rocks. The sandstone is absorbent or hygrometric, frequently covered with a white saline efflorescence, and contains both carbonates of lime and magnesia in its composition.* Its colour near the top of the group changes from the prevailing dull purple to much paler shades, in places banded with warm yellowish streaks.

Composition.

Dr. Fleming's and Mr. Theobald's descriptions of this sandstone group vary somewhat. The former describes it as containing conglomerate and ripple marks, the latter as never containing a pebble and having none of these markings. As a rule, no doubt, Mr. Theobald is correct in these particulars, some earthy conglomerate bands in the western part of the district being only doubtfully referable to the formation; but it would scarcely be safe to assert that ripple marks never occur in these sandstones, though they are certainly not characteristic of the group.

In one exceptional instance only, in the eastern part of the range, a marked difference in the arrangement of these beds was met with, a strong band of greenish-gray flags and shales appearing to intervene between the red marl and purple sandstones at the base of Dandôt cliffs. The occurrence being quite unusual, it is very probable that a concealed fault or other dislocation has placed the next overlying group in an apparently inverted position, and even though traces of the break have not been found, its presence may be almost presumed from the many dislocations of the rocks of the vicinity.

Exceptional appearance of a dark shale band.

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* Dr. Fleming's 2nd Report, p. [illegible]

Thickness and distribution.

The thickness of this purple group varies somewhat, but its prevalence all over the eastern part of the range is very constant; here it generally forms the first cliff rising out from the talus or broken ground, as at Tilla, Chambal (east), along the escarpment from Jalálpur towards Pind-Dádun-Khán and away to the west. In this direction it gets very gradually thinner and no longer shows itself so prominently amid the dislocated masses of other rocks, but along the edge of the plains traces of it appear the whole way to near Músa-khél, while in places within the glens it seems to have quite died out. From this part of the range to the Indus it cannot be said to exist, at least not in its usual form, being replaced by a clayey conglomerate of metamorphic pebbles.

Unfossiliferous.

The group has always proved unfossiliferous, nothing more than obscure and doubtful traces of fucoids occurring in it, and these but seldom.

The thickness of the *Purple sandstone* group varies from two hundred to about four hundred and fifty feet.

SILURIAN.

Position.

No. 3.—The *Obolus* or *Siphonotreta* beds show prominently in all the eastern sections, forming an inclined talus along the top of the purple sandstones; and exposed as belts in the cliffs or caps to projecting spurs. They consist of dark or blackish sandy shales drying of a dull purple colour, full of black glistening polished surfaces on the planes of lamination. They are often micaceous and interstratified with crystalline calcareous glauconitic-looking layers or sandy and conglomeratic bands, but the dark shaly character generally distinguishes the zone, which is much better defined in some places than in others. Strong ripple marks are seen occasionally.

Structure.

Organic remains.

In two places—one in the Khewra gorge above where the fresh water is taken off for the use of the miners, and the other in a deep ravine nearly a mile east of

Játána, close search led me to the discovery of some little bivalves numerously scattered through a small thickness of the sandy micaceous shale. The shells are very thin, no pair ever occurring in position, and are frequently crushed, flat, and broken. With great care and trouble Dr. Waagen was able to free the internal aspect of a few of the valves (the outside only being visible in some hundreds of specimens), so as to enable them to be determined as belonging to two species of *Obolus* or *Siphonotreta*, genera only found in silurian rocks. The discovery of these led to the hope that some other fossils might be detected, but nothing except fucoids or annelid markings has been obtained by further search, and I was obliged to rest content with the proof that the Salt Range contained even older palæozoic rocks than the carboniferous formation discovered by Dr. Fleming.

Places where seen, and definition.

This silurian sub-division is well defined on Mount Tilla, Chambal Mountain (east), on the north-west side of Diljaba, from Jalálpur to Khewra, and thence to Makrách, but beyond this westward becomes divided by light-coloured sandstone bands and loses much of its definite appearance. The characteristic shaly portions can nevertheless be often recognised (though of a greener colour), bending into the gorges and forming the middle of the cliffs as far as the Sungle Wán north of Nálli.

In a few places—as, for instance, along the track from the Vesála springs to Pail—conglomeratic bands occur in this group, the included pebbles being small, and as is usual in all deposits of the range older than tertiary, being exclusively of crystalline rocks. The thickness of the group varies from twenty to one hundred and fifty feet.

MAGNESIAN SANDSTONE GROUP.

Character.

No. 4.—The next group above that with silurian fossils presents a strong contrast to it, and in a great measure owing to the association of the two, forms some of the most marked cliff features of the escarpments of the range. In this character it replaces the nummulitic limestone wherever the latter is

absent or inconsiderably developed; but, possessing itself only a limited lateral extension, gives place again in this respect to other beds.

The group is characterised in many places, particularly to the eastward, by the prevalence of certain hard, light cream-coloured, or whitish bands of dolomite and massive calcareous dolomitic sandstone rock, sometimes weathering after the manner of limestone,—sometimes showing on the weathered surface strangely arranged markings like the sections of flat lenticular patches of more compact texture than the rest, but never the smallest trace, so far as known, of any kind of organic structure. This variety of rock has been called by Dr. Fleming magnesian sandstone, and stated to have the following composition* :—

Composition.

White quartz, sand	28·000
Carbonate of iron with a trace of alumina	7·313
Carbonate of lime	32·874
Carbonate of magnesia	31·199
Loss	·614
Total ...	100·000

Doubtless its composition varies much, and this analysis appears to have been obtained from a highly calcareous and magnesian portion on Mount Tilla. The more massive beds frequently present a peculiar brecciated appearance, as if the rock had been broken by pressure and re-cemented. Associated with these harder beds are strong, light coloured sandstones, sometimes with oolitic layers or more flaggy bands, often separated by greenish and dark-coloured shales, the flaggy portions being occasionally covered with obscure lumpy fucoidal or annelidan markings. Unless the oolitic bands should be found to contain microscopic organisms, the whole group would appear to be unfossiliferous otherwise than so far as stated.

Organic traces.

* *l. c.*, page 255. As the rock contains more than 28 per cent. of carbonate of magnesium, it ought, according to Cotta, to be called dolomite. Calcareous dolomite sandstone would seem most applicable.

The group with its most characteristic rock is well seen upon Mount Tilla, but is hardly represented on the neighbouring Chambal Mountain. It re-appears on Diljaba and Kárangli (where it contains small crystals of galena), and is well marked from Jalálpur towards Khewra, but beyond Makrách loses much of its individuality. Its sandstones being often separated by shales, it no longer forms marked features, its best exposures being on the spurs or among the dislocations and subject to the obscurity which they entail. Notwithstanding this, however, at Makrách and a little to the westward, greenish and hard white sandstones with dark, in places carbonaceous, shales and numerous large fucoids on the bedding surfaces, occupy the place of this group and underlie the next, proving the succession different from that apparent to the east.

United with the group below, &c., by other observers.

Dr. Fleming unites the group No. 3 with this in one of his divisions, although each possesses, where well developed, a strong lithological character of its own; while Mr. Theobald would, on the other hand, apparently include the present group with No. 10, with which it is seldom in contact; at least it is difficult to account for the conglomerates he describes among the magnesian sandstones on any other grounds. Conglomeratic layers there may be here and there so trifling as to escape notice, but strong conglomerates form no prominent feature of the group, even in its western most sandy and most divided portion.

Why separated.

In the direction of Makrách and to the westward, both this group and No. 3 might be included in one; but even beyond that locality, the lower shaly zone being traceable much further than the overlying sandstone, &c., and both being more closely related to each other than to the beds either above or below them, it appears better to preserve the petrographical distinction, principally because the want of palæontological evidence makes it impossible to assert that this group, like the lower one, is silurian.

The thickness of this dolomitic and sandy group, where well developed, is more than three hundred feet, and its average may be between one hundred and fifty and two hundred feet.

If we were to follow the apparently natural and conformable succession from this group upwards anywhere about Khewra or the neighbouring eastern part of the range, the following beds would occur in succession: first a brilliant red group, then olive beds, and then a limestone group finally overlaid by a mass of grey and greenish sandstones and reddish clays. The sequence would be true and natural no doubt, but not the whole truth, for four other zones having their places between this *magnesian sandstone* and the *"olive beds"* above-mentioned would be unnoticed, not being present in the eastern area.

SPECKLED SANDSTONE.

Commencement.

No. 5.—Of these four groups the first indications of that which properly succeeds the last become visible to the westward about Makrách; the group rapidly increases in thickness, and extends throughout the range, its importance growing less beyond the Chiderú hills, but the beds appearing frequently along the southern edge of the larger elevations culminating in Tredian Hill, and being only lost amid the complicated dislocations in the neighbourhood of Márí on the Indus.

Constitution.

This group of beds consists, as a mass, of light-coloured and reddish or purplish speckled sandstones alternating with red clays and shales, and including some very distinctly marked lavender-coloured and purple or grayish argillaceous and gypseous bands. The latter from their deliquescent nature yield so rapidly to the action of the weather that the original rock can seldom be seen, so thickly is the outcrop covered with its own detritus in the form of sun-dried or powdery mud.

Lavender clays.

These bands occur at various heights in the group, but are generally

prominent as a thick mass forming its upper part.* As might be expected from the weathering of these beds, saline efflorescences are common on their surfaces.

Copper shales.

These lavender clays are the beds apparently alluded to by Fleming† and Theobald‡ as "cupriferous shale" and "copper shales" some stress being laid upon their occurrence by these writers more than might have been the case if a fancied analogy had not been perhaps suspected between them and some European cupriferous beds of triassic and new or old red sandstone age. Dr. Fleming says the occurrence of little nodules of sulphuret of copper was first made public by Captain Hollings, Deputy Commissioner of Leia. The quantity, however, was insignificant; it was quite so in a commercial point of view according to Mr. Theobald. The ore is said to be found in grains "rarely larger than a pea" on the surface of the beds, particularly after rain, when the green colour of the nodules brings them prominently into view. That they cannot be very prominent may be gathered from the fact that after repeated search I have failed to discover them *in situ*, the only specimens I have seen being a few in the possession of one of the Salt Customs Officers who did not know exactly from whence they came.

Colour.

The colour of the whole group of sandstones is very often reddish, though the sandstone beds in detail are generally speckled, containing greenish or purple patches, or layers, of no great size. This redness is supposed to result partly from oxidation of iron in the rock, or more mechanically from the absorption of water coloured by the washing of the red earthy bands. Ripple marks and signs of oblique lamination may be frequently observed, as

* The colour, texture, and whole aspect of these clays are very similar to those of the lavender clay patches associated with the Khewra and Nílawán trap: they also remind one of the lavender-grey portion of the lateritic clay deposits of Kachh, which are also often saline.—See Memoirs of the Geological Survey of India: "On the Geology of Kach," Vol. IX, pt. 1, p. 68, &c.

† Second Report, p. 257. ‡ As. Soc. Beng., Cit.

well as some obscure fucoid markings and plant impressions—the only traces of organic life the beds seem to possess.

Peculiarity.

If these sandstones have any one peculiarity more likely to aid in distinguishing them than another, it is the occurrence of numerous small wart-like concretionary knobs projecting from their weathered surfaces (a feature sometimes common also in the Barákar and in some Máhádéva sandstones of Central India as well as among the upper beds of the jurassic series in Kach). Mr. Theobald says they are chiefly composed of the sharp sand of granitic rocks, and sometimes have a porphyritic aspect owing to crystals of felspar being present.* Some of the coarser beds have an arkose look, but I can hardly argee with him that any general or special character of these rocks which I have seen is sufficient to "afford unquestionable indications of the simultaneous existence of volcanic forces in the vicinity."

Conglomeratic beds.

From the Makrách to the Sardí glen the lower part of the group, for a thickness of one hundred or one hundred and fifty feet, is often seen to consist of brownish and light-coloured sandstones with some whitish flags and dark shales, as well as bands of conglomerate, the pebbles in which are of granite, syenite, and other crystalline, trappean, or metamorphic rocks, this portion having a general resemblance to some of the beds of group No. 10.

Irregularity of succession.

On reference to the diagram on Plate VIII it will be seen that another group ends just about where that under notice commences, and the idea may suggest itself whether the two are or are not continuous. The sections in this neighbourhood, however, show here and there a red band above the sandstones of No. 5, which may possibly be the last remnant of group No. 8. The latter before reaching this place gradually diminishes in thickness for a

* Mr. Theobald's paper to As. Soc. Beng., pp. 661, 662.

long distance, evidently disappearing from the series, besides which it has hardly a petrological characteristic in common with the group No. 5, though both are arenaceous and partly argillaceous deposits, and both, for all useful purposes, unfossiliferous.

This group, No. 5, is even at its commencement conglomeratic in places. It is occasionally so throughout its extension, and far to the west, where the groups 2 and 5 lose in thickness greatly, the conglomeratic character increases, the paste being often earthy and the enclosed fragments large boulders of crystalline rock; but it is rather uncertain whether these beds may not belong to the "*Purple sandstone.*" The average thickness of the group where well seen is from two hundred and fifty to four hundred feet.

Carboniferous Limestone, &c.

No. 6.—We come now to a very interesting formation, the carboniferous rocks of the Salt Range which have attracted so much attention. The most prominent beds of the group are grey limestones, in colour, texture, and very frequently in the general aspect of their organic remains, undistinguishable from much of the carboniferous limestone so largely developed in England and Ireland. As in the latter country, magnesian limestones are also common. Shales often predominate at the base, succeeded by yellowish and reddish sandstones with *Spirifer* and fish remains (teeth, &c.), sometimes containing strong bands of black coaly sandy shale. The upper parts of these sandstones are in places often highly fossiliferous with *Fusilina*, *Aulosteges*, *Productus*, *Spirifer*, &c., and are succeeded by limestones, dolomitic or otherwise, with *Goniatites*, *Ceratites*, *Strophalosia*, *Athyris*, *Streptorhynchus*, several species of *Productus*, *Spirifer*, *Retzia*, *Terebratula*, *Macrocheilus*, *Fenestella*, *Polypora*, *Retepora*, Crinoids, and many other of the carboniferous forms, such, for instance, as are mentioned in the papers of Davidson and de Koninck already referred to. The

Limestone.

Other rocks.

Fossils.

Sandy upper strata.

upper strata are again sandy; or light-coloured sandstones even, among which are intercalated coaly shales and argillaceous beds, reappear, one thick sandstone band being crowded with a globose species of *Bellerophon*. The sections differ much in different places; occasional sandstone bands may occur anywhere, and not unfrequently the solid grey limestone has been found directly overlying the lavender clays at the top of the sandstone group below. The limestones vary in colour from grey to black, and several of the magnesian bands are of a warm yellow colour. The beds are more commonly compact than crystalline and are sometimes crinoidal, chert layers and nodules being in places very common.

Different sections in different places.

Dr. Fleming has sub-divided these rocks into three groups, the middle one of which he distinguishes as micaceous, fine-grained, fissile sandstone, alternating with beds of dark bituminous shale. Whether such a division could be carried out or not Trans-Indus seems doubtful, and as no such grouping has been found to characterise the Cis-Indus carboniferous formation, it is very probable that both Dr. Fleming and Mr. Theobald, in forming their triplicate classifications of the beds, took the main part of this formation for their two lowest groups, and made their third of the triassic beds.

Fleming's and Theobald's three-fold sub-division.

These writers also allude (the latter with much doubt) to the occurrence of both *Ceratites* and *Orthoceratites* in these beds, and Dr. Fleming gives a drawing of a piece of rock in which *Ceratites* and *Orthoceratites* occur together. Mr. Theobald had never seen an *Orthoceratite* along the range, but suggested that parts of *Belemnites* might have been taken for them. The fact is that both of these forms do occur in the triassic limestones, the *Orthoceratites* being, however, rare, and the forms figured in Fleming's plate are not from the carboniferous, but were recognised by Dr. Waagen as from the triassic beds above. The *Ceratites*, which are most of them new, and all different from

Their allusion to *Orthoceratites* and *Ceratites*.

the carboniferous species, occur in much the greatest abundance in the triassic group.

Discovery of *Ammonites.*

But a stranger fact even than that alluded to has been already noticed, namely, the discovery by Dr. Waagen, at a place about a mile north of Jabi, in a land-slipped mass, of the carboniferous limestone (belonging to the lower portion of its upper part) of an unquestionable but altogether unique *Ammonite*, or, as he has called this form, *Phylloceras*, associated with *Goniatites*, *Ceratites*, *Athyris Royssii*, several well-known species of *Productus*, *Terebratula Himalayensis*, *Fenestella*, and other carboniferous fossils. In the progress of the survey, several *Goniatites* and nodose *Ceratites*, closely resembling *Ammonites* in exterior form, were collected; but here at least a genuine one was found, the oldest known occurrence of that genus.*

Magnesian beds.

The magnesian portions of the limestones are, as Dr. Fleming says, generally interbedded, and where they cross the stratification† all the relations of the rocks are obscure. The magnesian rocks are in places not wholly unfossiliferous, Echinoid spines, and parts of a few other fossils, often corals of silicious composition, weathering out from the surface.

Commencement and development of the formation.

The *carboniferous formation* commences in the fine cliffs on the west side of the Nílawán ravine, *below* the beds recorded as carboniferous in that locality by Dr. Fleming and Mr. Theobald. The rocks here are coarse, light-coloured, yellowish-grey and greenish sandstones with coaly laminæ and a band of sandy calcareous shales. The sandstones contain *Productus spinosus*, and the whole group, having a thickness of sixty or seventy feet, immediately succeeds the lavender clays, &c., of the group below. From this westward the carboniferous beds are much

* See Mem. Geol. Sur., Vol. IX, pt. 2.

† This vertical arrangement of magnesian portions of carboniferous beds often occurs in Ireland.

concealed, but they reappear with largely increased thickness in the part of the Verála] scarp towards Pail and in the immediate vicinity of that village. Still further to the westward they develope rapidly into an important member of the series, having a thickness of at least four hundred and fifty or five hundred feet, which would appear to be mantained as far as the Chiderú hills. In the narrow part of the range connecting these hills with the Tredian cluster, the thickness appears less, but increases in the latter hills near Swas. With the extension of these hills towards the Indus the thickness again decreases, and the formation strikes obliquely out towards the plain and disappears at Khyrabád.

Features.

These *carboniferous* limestones in their greatest development carry on the scarp feature usually formed by the *nummulitic limestone*, but with less regularity, being often subject to intense contortion and slippage. The peculiarity of the way in which they are sometimes decomposed *in situ* as mentioned at page 59 is well seen about Jalar lake and towards the Kavhád glen, while the country which they occupy, with its rolling ground, sheeted by fragmentary debris, its steep precipices and deep ravines, has an aspect peculiarly its own.

TRIASSIC CERATITE GROUP.

Place.

No. 7.—Immediately succeeding the *carboniferous* rocks is another interesting but smaller formation, the existence of which was suggested by the doubts felt with regard to the place of some of the fossils sent by Dr. Fleming and Mr. Purdon to Europe for examination. The lowest beds of these *triassic rocks* are generally thin limestone with *Ceratites*, succeeded by a thick marly zone, that yields much to atmospheric disintegration and weathers of a light greenish colour, which enables the band to be distinguished from a considerable distance. These are overlaid by grey sandstone and flaggy limestone layers with many *Ceratites*, passing upward into grey nodular marls. Hard limestones and calcareous

Lowest beds.

Succession.

sandstone beds with spinose *Ceratites*, marls, limestones, and sandstones, form the upper portion of the group, and contain, besides *Ceratites*, numerous specimens of *Gervillia*, a *Cardinia*, *Rhynchonellæ*, *Anoplophora*, *Orthoceras*, &c., being generally characterised by a predominance of bivalves.*

Magnesian.

The succession varies frequently as to details, and some of the limestones are magnesian, or dolomite bands take their place. Sometimes layers of glauconitic limestone (or pisolitic limestone with glauconite) occur, and beds of conglomerate, in one instance formed of huge limestone blocks, are sometimes present.

First appearance.

This representative of the Trias first appears in the neighbourhood of Kúra† and Katwáhi, and extends thence to the westward, except where interrupted by dislocation. It also occasionally occurs in isolated or surrounding outliers as near Virgál. It is well seen near Chiderú, and from the vicinity of Sakesar accompanies the carboniferous formation everywhere to its disappearance at Khyrabad.

Ceratites.

The group is characterised throughout by the number of *Ceratites* which it contains. Certain species of these prevail in certain zones, and one band is marked by a predominance of the genus *Bellerophon*‡—an instance of geological history repeating itself, the same genus occupying, as has been said, a strongly marked zone in the upper part of the foregoing group.

No strong lithological contrast.

These *triassic* rocks, though lithologically distinguishable, present no such marked contrast to the *carboniferous formation* as exists between the *Trias* and succeeding beds. The limestones are more thin-bedded, and the shales or marls of

* This information as to fossils is given from Dr. Waagen's notes.

† This name must be distinguished from Khewra. It is exactly represented by the old spelling "Koora."

‡ Dr. Waagen.

different character and somewhat different colour; but the whole aspect of the group is such that, were it not for the palæontological evidence, it might pass for a portion of the palæozoic rocks immediately below with which it was classed by Dr. Fleming. The thickness of the formation is very much less than that of the carboniferous beds, being on an average a hundred and twenty to two hundred feet or sometimes even three hundred feet.

PSEUDOMORPHIC SALT-CRYSTAL ZONE.

Character.

No. 8.—The thin-bedded and flaggy sandstones with intensely red shales or clays, which form this group, have been separated from the rest of the series, principally on lithological grounds, and although the rocks differ widely in appearance from the Ceratite-bearing *triassic* beds, I have been induced to place them with or near the latter for the following reasons: *First*, superposition shows them to form a newer sub-division than all the rocks up to the *Magnesian sandstone,* inclusive. *Secondly*, they thin out towards the sandstone No. 5, which comes into the series near their termination but at a lower level in the cliffs about Makrách. *Thirdly*, they possess no similarity to the *carboniferous* formation, nor yet to the associated *triassic* rocks, while they have some analogies of colour with the succeeding *jurassic* beds, and if placed between the two latter might form a transitional group.* It will be seen on reference to the diagram that this group No. 8 is separated by a distance of nearly forty miles from both the known *triassic* and *jurassic* groups; its position would correspond to that of an outlying portion of either of these, or of the *carboniferous*, but the total absence of fossils would seem to dissociate it from each. From above downwards it comes into the place of the *jurassic* beds, and the only characters left to aid in fixing it are its red colour, unfossiliferous nature, and the presence

Reasons for supposing these beds Trias.

* It was after discussion with Dr. Waagen that I was induced to classify this group with the Trias. In the absence of palæontological evidence I was inclined to give it a separate place by itself, but Dr. Waagen seemed to think there was sufficient probability to warrant its being provisionally included as a part of the triassic group.

of numerous pseudomorphic casts of crystals of common salt. These might be taken to indicate for it a triassic horizon as an isolated deposit of the period, to which also its general place in the series would accord.

It must be admitted that this method of identification is open to much objection, as it closely resembles the erroneous reasoning which led to the red salt marl itself being thought triassic; but for want of better grounds, in adopting for it provisionally the place here indicated, I am compelled to take advantage of all petrographic aid where fossils are non-existent, and in classifying the group as triassic, to do so with the reservation that it may belong to any of the three formations (Nos. 6, 7, or 9) named, and if not to the upper part of the *triassic* beds, possibly to the *jurassic* period.

Local difference.

As in almost every group of the range, the sections in this present local differences. Where best developed the lower portion is the most flaggy, the flags being outwardly red, but often greyish or whitish inside. Here the upper part of the zone, which is thicker than the lower, is formed of red and liver-coloured, variegated, argillaceous beds, passing upwards from shales into clays. In other places variegated purplish and red clays and shales predominate below, and where the group is thinnest, it is generally formed of flags, to the exclusion of most of the shales and clays. The more earthy portions disintegrate into minute angular fragments, and sometimes contain little nodules of

Hæmatitic concretions.

hæmatite used by native shikaris as bullets. Greenish spots or veins or layers are common, as is often the case in ferruginous rocks, but the most characteristic marks of the group are the cubical salt pseudomorphs or casts which prevail almost everywhere in the more flaggy layers. These separate so as to show the casts thickly studded over the lower surfaces of the flags, a solid angle of each cast generally projecting. Similar pseudomorphs of salt have been noticed by Strickland at Blaisdon in Gloucestershire, and by Professor Phillips at Spetchly in Worcestershire.* According to Dr. Warth they

Salt pseudomorphs.

* Jour. Geol. Soc. Lond., Vol. IX, p. 5.

also occur in Cheshire above the salt, and in Germany in the Keuper formation overlying the salt-bearing Muschelkalk. He explains their occurrence by the evaporation of brine, the crystals being formed partly in mud left dry sufficiently long to harden. Salt water or weaker brine again flowing over this mud would dissolve the salt and deposit mud or sand in its place, forming casts of the crystal moulds, which would adhere to the under surface of the upper layers. In the cases quoted first, however, the casts were observed both on the upper and under surfaces of the layers, from which it would appear that the crystals were enclosed before they were dissolved, or were developed near the surfaces subsequently to the deposition of these layers, their adhering to one surface or the other being matter of accident.

Formation.

The only organic traces observed in these beds were obscure fucoid impressions, or tracks like those of worms. They frequently exhibit very perfect ripple marks, sometimes crossing each other in different directions.

Organic traces.

Whatever may be its precise place in the general series, the group is a local one. It is present from Mount Tilla to Makrách in one direction, appears at Diljaba on one side, but is absent at Chambal Mountain (east) upon the other, and attains its greatest thickness near Bhåganwála about midway between these points. Here unfortunately the beds undulate greatly at low angles, so as to render observations of the thickness uncertain, but measured sections across the strike, reduced to compensate for possible error, gave a thickness of over three hundred feet for the upper earthy portion and one hundred and fifty feet or more for the sandstone and flags below, so that from four to five hundred feet may be a fair estimate. Where the group is thinner, as at Mount Tilla, Diljaba, and towards Makrách, it may vary from one hundred to fifty feet and even less where dying out both to the east and west.

Distribution.

Thickness.

This disposition of the group suggests that it may have occupied an isolated estuarine or lacustrine situation; the thin-bedded and ripple-marked characters point to the existence of shallow-water currents, while the mass of clays and shales would indicate a change to still and deeper water; but the source of the ferruginous colouring matter which separates it so decidedly from the associated groups is quite unknown.

Lacustrine and estuarine.

JURASSIC.

No. 9.—In upward continuation of the section in which the *Ceratite*-bearing portion of the *trias* occurs at the western side of the district, is a very varied and mingled group of arenaceous, argillaceous, and calcareous rocks, liable to considerable change laterally, in thickness and composition, but preserving a well-marked individuality of aspect, by which it can generally be recognised without difficulty.

Situation.

In the lower part of this series strong bands of thick-bedded, soft, ferruginous sandstone, of red, variegated, or yellow colour, alternate in places with liver-coloured and grey ripple-marked bands. To these succeed thick, argillaceous, yellow limestone, soft rusty-looking sandstones, grey gypseous and pyritous clays and soft, powdery, white sandstones, apparently largely composed of white quartz and felspar grains in a white earthy or chalk-like matrix.

Lower part.

Among these beds and in the body of the group, bands of hæmatite several feet in thickness occur, and thinner layers of "golden oolite," each grain having a burnished ferruginous coating (this latter rock exactly resembling in character the golden oolite of Kach and resulting from the decomposition of an oolitic limestone). Above all these are coarse brown sandstones and yellow marls or mudstones, white cavernous sandstones, and bands of grey hard limestone of inferior thickness and less constant occurrence than those below.

Hæmatite.

The sandstones are sometimes conglomeratic, and limestones are more largely developed in the western extension of the group. Frequently the rocks are fossiliferous, numerous indefinite plant fragments* occurring in the sandstones in the golden oolite and more calcareous beds—*Ostrea*, *Exogyra*, *Terebratula*, many Gastropods, unsymmetrical Echinoid fragments, and generally in the upper region *Belemnites*, and possibly *Ammonites* (these last being locally numerous Trans-Indus).

Composition.

Fossils.

There are associated with this group at Chiderú beneath Síran-ki-dôk and near Kyrabád, a very considerable thickness of light grey incoherent sandstone or slightly compacted sand with many alternations of orange-coloured or drab clays. This soft group in some places appears to belong to, and in others to be discordant to, the rest of the series, so that I have been unable positively to include it with them, more particularly because its whole aspect is almost exactly that of one of the upper members of the great tertiary sandstone-and-clay series, parts of which might have been introduced by fracture or even unconformable deposition among the older rocks.†

Incoherent beds.

The upper limits of this *jurassic* group are rather indefinite, a gradual transition appearing to take place upwards into the newer beds, and the junction with these being, as a rule, concealed by a talus of debris from the cliffs above.

Upper limits.

In the western parts of the district along the southern side of the Tredian hills, these upper beds partake of the general contortion and disturbance to a degree

Disturbance.

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* At page 269 of his larger Report, Dr. Fleming notes the occurrence of very perfect fronds of ferns in the lower argillaceous beds of this group. The general accuracy of his observations led me to frequent but unavailing search for these, and only a few imperfect fragmentary fern impressions have been found.

† These possible unconformities have never been established, and the localities are among too many faults and disturbances to encourage belief in them.

which renders their boundary most difficult, and sometimes impossible to follow in close detail, through that wild, rugged, and frequently precipitous country.

Commencement.

The whole group commences in cliffs west of Jalar lake, reaching along the southern escarpment of the Són-Sakesar basin, where it is interrupted by faults, but it reappears in the fine cliffs south of Sakesar summit, and it is also exposed by erosion on the northern slopes of that mountain. From Sakesar north-westwards it extends with some interruptions along the narrow part of the range and through the Tredian hills to Khyrabád.

Thickness.

The thickness of the formation may be estimated at five hundred feet where fully developed.

Cretaceous.

Passage beds to west.

No. 10.—The *jurassic* rocks, as has been just now stated, pass up with an apparent lithological transition into the nummulitic series in the west of the district; some of the intervening bands just at the base of the eocene, however, contain fossils of a different aspect from those of the immediately overlying rocks. Dr. Waagen remarked a typical resemblance between these fossils of the lower beds and those of the Ronca or Italian eocene.* They have only been observed in the Bakh ravine southwards from Namal, and they may be taken to indicate the limit here between the mesozoic and tertiary epochs.

Ronca type of fossils.

Eastern representatives.

In the eastern parts of the district, however, there occurs a very considerable group of sandstones, of dark greenish, greyish, white-and-yellow striped, yellow-and-grey spotted, or olive or whitish colour, in the upper part of which coaly seams occur with some shaly bands, while in the lower part are strong bands of conglomerate, or thick, dark, trappean-looking shales filled with

* From information given by Dr. Waagen.

boulders. The enclosed rounded fragments in these are always of crystalline rocks and sometimes of great size. Passing westwards among the

Western beds.

upper beds of the group, brown, variegated, and dark green sandstones, with granules of phosphate of iron, are associated with calcareous layers, marls, and coaly bands, and sometimes with bands of hæmatite. In some of these western localities the sandstones and calcareous layers contain large *Nautili*, long thin spines of the genus *Cidaris*, other *Echinidæ*, *Astrea*, and the *Terebratula Flemingii*,

Fossils.

to which attention was called by Mr. Davidson as unlikely to be of carboniferous age. Far below all these in eastern parts of the group, thick, greenish-olive, deeply-weathered sandstones enclose considerable numbers of the casts of large bivalves as yet undeterminable, but, like all the other fossils collected from these rocks, possessing a cretaceous rather than a newer aspect.*

The whole group, which from its prevailing colour I have called

Distribution.

the "*Olive group*," resembles many of the others of the range in the irregularity of its distribution. It is absent at Mount Tilla and Chambal Mountain (east); may be said to commence in the hills near Bháganwála, and increases gradually towards the eastern plateau, over which and on Diljaba Mountain it is most largely developed. The lower shaly, block- or boulder-conglomerates † are especially well exposed as to quantity at the north-eastern part

Where seen.

of Chél hill, and the whole group may be traced on the south side of Kárangli hill round the edges

* Dr. Waagen. I found some small-ribbed protuberances on weathered surfaces of the sandstones belonging to this group in the Jutána Beat, which struck me as peculiar from their always occurring in pairs. Though very indefinite, Dr. Stoliczka, on seeing them, suggested at once their being the opened valves of *Trigonia* lying close together.

† A block of red granite, of about 100 cubic feet, believed to have been derived from these beds, but now lying on the "Saline Series," occurs to the eastward of the Salt Collector's bungalow at the Mayo mines, Khewra. Another very much smaller, well-rounded boulder, also fairly supposed to have lain in these conglomerates, was discovered lately by Mr. Theobald to be glacially striated. He found it near Kárangli on the eastern plateau.

and depressions of the eastern plateau near Sálowi, Kúsak, Choya-Saidan-Sháh, Pid, above Khewra, and around the Dandôt table-land. From this westwards by Makrách, Malôt, and Sardi it becomes thin, but is still represented in the Nîlawán ravine and by a narrow band as far as Nursingphoar, beyond which it has not been observed.

Where strongly developed, the thickness of the group is fully three hundred and fifty feet, declining to a hundred and fifty feet or less in other places.

NUMMULITIC.

Large development.

No. 11.—The *Nummulitic* group is one of the most largely developed and structurally important of the whole series. It is mainly formed of fine compact grey or white limestone, frequently cherty and sometimes variegated, pink and grey, having rarely a curiously waved or concentric banded appearance marked by lines of lavender, yellow, grey, and reddish tints.

The limestone.

The highest beds present no great difference of colour or texture from those much below them, but the lowest part of the group is generally formed of rudely concretionary, pale yellowish marly beds of great thickness, with some bands of light-coloured friable sandstone, grey shale and hæmatitic layers. The massive and homogeneous character of this limestone as a group has been doubtless the cause of some of the most striking physical features of the range, of many of its finest cliffs, and of all its plateaux.

Coal shales.

Immediately below the light-coloured marly limestones there is a band of dark gypseous shales, very commonly but not constantly developed; in these occurs the Salt Range coal, in strings and beds of very variable thickness and inconstant character. Both shales and coal are very frequently pyritous, and in consequence of the destructible nature of this part of the series, as compared with the overlying limestone, the latter, being deprived of support along the outcrop, has parted vertically and fallen away, leaving sheer precipices behind. The coal-shales to the west as exposed

in the Bakh ravine occupy an unusually high place in the series, being more nearly in the middle than at the base of the nummulitic group.

Beds below them

Just beneath the coaly shales are sometimes a few beds, and sometimes a greater thickness of friable white or red or olive sandstones with grey shales or clays interstratified. In some places a thick mass of dark lumpy foraminiferous limestone occupies the place of these, and frequently the base of the whole formation is marked by a variegated white and red clayey hæmatitic band which often assumes the character of pisolitic hæmatite or the brownish look and polished surface of earthy laterite. In the eastern parts of the district the beds beneath the solid limestone are sometimes over a hundred and fifty feet in thickness.

Fossils.

Fossils are numerous in the group. In the lower shales and sandstones plant fragments are common, and in the dark shale lanceolate and other leaves have been observed, while in the light yellow lumpy limestone casts of large Gastropods, such as *Conus*, *Cypræa*, *Cerithium*, *Strombus* and others, are frequently found; very large *Echinidæ* also occur. At higher stages than these, casts of *Cytherea*, *Astarte*, or *Lucina* and other bivalves are often met with. *Nummulites* are common throughout, but most prevalent in the lower beds, where *Orbitolites* and *Alveolina* also occur. The assemblage of fossils, though numerous enough to fix the age of the rocks and more numerous than in other nummulitic beds of the north-west Punjáb, is poor compared with that of distant groups of the same age,—such, for instance, as seen in Kach; and the organisms, as a rule, are badly preserved, existing chiefly as casts with little or none of the originally shelly parts remaining. Small bullet-like concretions of iron pyrites are common in many parts of the limestone.

Thickness.

The coal-shales have a thickness varying from about fifty to more than a hundred feet to the westward, and the whole of this *lower part* of the group, including the coaly shales and associated sandstones, or limestones where well seen, may be esti-

mated at a hundred and fifty feet, becoming nearer three hundred feet towards the Indus. The limestones from various measurements and estimates have throughout most of the range a thickness of four hundred to five hundred feet, becoming thicker to the west, thinner on the eastern plateau, and disappearing entirely in the hills between the meridians of Bháganwála and Jalálpur. The whole group is absent from the series on Chambal Mountain (east), and north-by-west of Jalálpur, but a narrow band of the limestones re-appears upon the northern slopes of Mount Tilla. The group is more largely represented upon Diljaba Mountain, terminating with dislocations in the Ghorágallí pass; and a faulted mass of these beds is seen again upon the Bakrála ridge over Domélí. At the western part of the eastern plateau these nummulitic rocks are disconnected by denudation and faulting from the rest of their mass, but from the Choya-Saidan-Shah valley they extend continuously throughout the remainder of the range as far as Khyrabád, several outlying portions occurring to the southward of the main exposure. Beyond Khyrabád these rocks are involved in the great dislocation which prevails, and they disappear entirely with the exception of a narrow faulted rib in the outer hills close to Mári on the Indus.

Extension.

This *Nummulitic group* of the Salt Range differs in many respects from the nummulitic limestones of other parts of the northern Punjáb, chiefly in the absence here of interstratified thick zones of dark-coloured shale, in its being uniformly of a light grey colour or nearly white, and, so far as seen, in never assuming the black or dark colour usual in other places. The general assemblage of fossils differs also, and the whole aspect of the group suggests its having been deposited under circumstances different from those which prevailed in the hill region to the north. In this direction it may possibly be represented by the light-coloured limestones, which Mr. Medlicott has identified as corresponding to part of his Sabáthú beds, external to and newer than the mass of the limestone seen in the hills.

Difference from other nummulitic limestones.

The petroleum which rises from the nummulitic rocks will be noticed hereafter.

TERTIARY SANDSTONES, CLAYS, &c.

Nos. 12, 13, 14, 15.—Everywhere from one end of the range to the other, and always on its northern and eastern aspects, the uppermost rocks of the Salt Range series are innumerable alternations of grey or greenish sandstones, of no great hardness, with red or light-brownish orange clays, more rarely with conglomerates, but frequently with harder fine-grained sandy beds of peculiar concretionary pseudo-conglomeratic structure. The enclosed concretions are of hardened, sometimes calcareous clay, of purple and yellow colour, in a somewhat calcareous matrix, and give the rock the appearance of a gravelly conglomerate. The alternating bands of sandstone and clay are from seventy to a hundred and twenty feet in thickness, being very frequently about a hundred feet each, but some zones are much thicker.

General description.

Mr. Medlicott, at page 91 of his Himálayan Report, remarks that all these sandstones, &c., rest upon a denuded surface of Salt Range *nummulitic limestone;* and this is supported by an observation in his paper on the Jamú country,* but without the confirmation that any denuded surfaces of the limestone had been observed; hence, the existence here of an important break in the series depends entirely upon the occurrence of an intervening conglomeratic layer "made up of water-worn pebbles of the limestone and its flints."†

Supposed unconformity.

* Rec. Geol. Surv., India, Vol. IX, p. 49.

† *Ibid*, p. 55. Many of these fragments have the forms of concretions, and none of any other than nummulitic rocks appear to occur amongst them. Almost immediately above the nummulitic limestone, or within 15 feet of it, a pseudo-conglomerate layer, such as is described in the preceding paragraph, contains small chert pebbles and some [illegible] crystalline rocks. It occurs on the hills above Fadiálá close to where the limestone conglomeratic bed is seen. This limestone conglomerate appears to belong more to the limestone beneath than to the overlying sandstones, &c.

Being aware of the earlier notice of this break, I had sought along the range for confirmatory evidence and noticed the abruptness of the change from limestone upwards to sandstone beds, but could never find erosion of the lower rock, while I observed in the contact layer, where present, a concretionary or nodular band rather than a regular conglomerate, though the latter occurred in the ascending section within 40 feet. In the trans-Indus country I also paid considerable attention to the point, and have described the junctions of the two groups in several places.*

I have observed at this horizon as well as both below and above it scattered pebbles of nummulitic or alveolina limestone. They were found in the intercalated lower nummulitic sandstones trans-Indus† and at different stages or horizons in the sandstone and clay series cis-Indus, but in all cases accompanied by the same perfect parallelism of deposition among the containing beds.

Nahan Group.

No. 12.—The *Nahan* beds of this district have, comparatively speaking, a limited exposure in the Bakrála ridge. They are the same beds which I had observed to present a strong similarity to some of the lower rocks of the north side of the Potwár, distinguished by me as the "Murree beds." Here at the Bakrála ridge they consist of purplish and grey sandstones, interstratified with many bands of red clay, which give to the whole group a reddish tinge; the sandstones are harder than those occurring at higher places in the series. This strong similarity to the red "Murree beds" is not found to the westward, and the character of the rocks appears to have changed laterally: many of the intercalated greyer sandstones, &c., being, however, identical on the Bakrála ridge and generally along the northern slopes of the Salt Range. Both the redder and greyer rocks of the Bakrála ridge contain some bone fragments and occasionally mammalian (*Mastodon*) teeth.

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* Mem. Geol. Surv., India, Vol. XI, pt. 2, pp. 64, 65, 66, 94, 102, 106, 114, 116, 118, 120, 126, 169, 170, 178.

† Rec. Geol. Surv., India, Vol. IX, p. 88.

In other places where the Nahan beds have not been recognised, the lowest rocks of the Salt Range tertiary sandstone series are slightly calcareous, often of the nature of the pseudo-conglomeratic gravelly-looking beds found higher in the formation. Their colour is pale purple or dull grey, passing rapidly upward into soft coarse sandstones of greenish or dull brownish and grey colours, containing locally crocodilian bones, teeth, jaws, scutes, &c., and pieces of exogenous fossil timber in considerable numbers.

Above these beds greyer sandstones prevail, and red clays or shales increase in quantity upwards, associated with occasional layers of pseudo-conglomerate and lumpy calcareous purple clay until the red beds predominate so as to form a marked "red clayey zone" with indefinite upper and lower boundaries. The bottom of the red zone has been adopted as the upper limit of Mr. Medlicott's Nahan rocks in this part of the Punjáb.

Siwalik.

Lower Siwalik, No. 13.—The "red zone" alluded to is commonly observable along the north side of the range, and on both sides of the Bakrála ridge, but to the west it is difficult to trace this red zone among the disturbed rocks at the Indus near Mári and Ainwa. The red band is succeeded by grey sandstones here and there, containing strings of lignite, alternating first with red, and higher up with warm orange clays, and some layers of conglomerate, in which mammalian bones, &c., occur. The pebbles in these conglomerates are usually of hard quartzose sandstone, but sometimes of limestone, and rarely of syenitic rocks; among them, pieces of purple or grey sandstone similar to those forming the harder varieties of the tertiary rocks are occasionally met with.

One of these conglomerate beds among the nearly vertical sandstones south of Mount Tilla between the villages Bidar and Hán was searched for evidence of later tertiary denudation of the Mount Tilla series, but the only recognisable detritus belonging to that series contained in this conglomerate were numerous pebbles of limestone enclosing

Nummulites and *Alveolina*, together with some fragments of purple tertiary pseudo-conglomerate; thus the vertical effect of the erosion which produced the pebbles appears to have been limited to the nummulitic and overlying beds. The remainder of the pebbles were chiefly of purple and grey quartzite, quartz, red syenite, and earthy ferruginous rock.

The grey sandstones and orange or drab clays continue to occupy the surface for a long distance from the Salt Range into the Potwár plateau, and they are also observable between the eastern spurs of the range. With the red and grey bed below they have been taken to form the lower sub-division of the Siwalik group in this country, that containing the greatest quantity of the fossil bones, for which this group has become specially famous.

Upper Siwalik, No. 14.—Resting conformably upon the grey and brown or orange beds, and passing into these, is a strong group of conglomerates and boulder beds sometimes consolidated, but often so friable as to have weathered down, covering the ground with their hard, mostly quartzitic blocks, and concealing their own outcrop.

The group has often a much greater thickness than in the vicinity of the Salt Range, but wherever its conglomerates are found *in situ* they are unmistakeable. If a local name were wanted for this group, it might be found in the word "Chainchal," commonly applied by the natives to its debris, from the hard pebbles of which the road metal for the neighbouring parts of the Grand Trunk Road is obtained. Such conglomerates as these might be expected to have a more or less local distribution, and they appear to be in places represented by a great accumulation of drab and pink clays on about the same horizon; those, for instance, of the Khariân hills,* or near the village of Bakrála south of the ridge of the same name. Bones, generally worn and rounded, are also sometimes found in the conglomerate group, which with some

* Mr. Medlicott, Records of the Geological Survey, Vol. IX, Part 2.

overlying drab or pink clays constitutes the highest known part of the Siwalik series.

The whole sandstone groups.

The whole of this Siwalik group locally abounds with ossiferous mammalian remains, but frequently for long distances no fragment worth preserving can be obtained. It has recently yielded to Mr. Theobald a large collection from the valley between the Tilla and Bakrála ridges, and numerous fossils have also been found in the vicinity of Lehri to the eastward.

The Nahan representative sandstones and clays, besides forming the northern foot of the Salt Range, rise upon its slopes near Kalar Kahár, overspreading a large depression in the limestone plateau and running upwards to the very margin of the Sardi glen on its western side. Several outlying portions of the group also occur on the top of the range, either left by denudation or previously to this having been faulted in among the nummulitic limestone rocks. Cases of this kind occur near Choya-Saidan-Shah, Dilwál, Sáhetti, near the heads of the Bhál portion of the Nílawán ravine, close by the village of Pail and north of the cliffs over Jalár lake, where these lower beds of the sandstone series contain large fossil (rib) bones.

At the termination of the Salt Range proper on the Indus, the chief exposures of the detrital tertiary rocks consist of the Siwalik sandstones and clays (with some which may be of Nahan age). Besides these, the only considerable exposure of any other group cis-Indus is of the red salt marl: the two extremes of the Salt Range series thus meeting, to the actual exclusion of everything else, in places.

The small quantity of petroleum found in these tertiary rocks and the stream washings for gold will be subsequently noticed.

The thickness of the tertiary sandstones and clays in the vicinity of the Salt Range must be great: the Nahan beds are about 1,900 feet in the Bakrála ridge, the lower Siwaliks may be 7,500 feet, and the

upper conglomerates or clays about 2,500 feet,—making in all, roughly speaking, 10,500 feet.*

Post-tertiary and Recent.

Post-tertiary.

No. 15.—A still more recent set of pebble beds than those of the Siwaliks, capping the hills over the Kahán gorge near Rotas, has been referred to the post-tertiary group, or older alluvial, or high-level river shingle of Mr. Medlicott's paper.† The same group was noticed long previously in the Salt Range (but included with the upper tertiary rocks) by Mr. Theobald.‡

I had noticed these beds in the Soan valley in the Potwár and in other places. They contain frequently a large percentage of limestone pebbles and sometimes are almost exclusively made up of either these or of the same pebbles which occur in the uppermost Siwalik conglomerate. It has been said that the latter conglomerate wastes away so as to furnish an enormous quantity of boulders covering the ground. Where these lie thickly and are cut through by streams, the unconformable mass exposed, though perhaps but quite locally derived, has exactly

* Mr. Medlicott has in his paper (Records, Geological Survey, Vol. IX, p. 49) indicated much of the difficulty which prevented the full recognition of his groups in the Northern Punjáb until he was able to traverse the country reaching from the typical Sub-Himalayan area to this district and identify them here himself.

Although the general characters of the Upper Punjáb Tertiaries agreed with the whole Sub-Himalayan series, I was unable previously to fix the divisions with any certainty, because I could find neither the same stratigraphical breaks in the series, nor an exceptionally ossiferous upper (or Siwalik) group.

I had previously pointed out that the whole of the Potwár sandstones, &c., were more or less ossiferous from the nummulitic (Sabáthú) upwards, and Mr. Lydekker's reference to fossils from some of the Mári beds near Kushialgar (Records, Vol. IX, p. 94) shows that the occurrence of bones is not sufficient to fix the rocks as Siwalik; the main characters for the determination of the boundary between the Siwalik and the Nahan or Murree beds in the field will therefore be position and lithological structure.

† Records, Geological Survey, Vol. IX, p. 55.

‡ Paper on the Salt Range, As. Soc. Beng., p. 672.

the appearance of the conformable Siwalik conglomerate group. In this way I found it difficult to account for the masses of pebbles resting unconformably on the edges of the Siwalik sandstone at the Rotas gorge, except on the supposition that the beds had been recomposed. Far away to the west at the village of Namal, these unconformable beds are again seen and without the accompaniment of Siwalik conglomerate in the immediate vicinity. The deposit near Rotas is at about 1,000 feet of elevation above the sea; the Namal pebble beds may be situated 100 feet higher, but there is a very similar deposit of boulder beds (that mentioned by Mr. Theobald in his paper on the Salt Range, p. 672), on the Sôn plateau of the Salt Range near Nowshera at a height of over 2,500, or even 2,700 feet.

Alluvium.

Besides the ordinary alluvium of the Rivers Jhelum and Indus, there are in the eastern parts of this district masses of superficial deposits much resembling the river alluvium, but, very rarely, containing fragments of the local rocks and often fairly stratified, the stratification being nearly horizontal. As the country is so much occupied by soft, easily abraded rocks, these fine deposits are very probably the waste of the tertiary sandstone and clay beds. They frequently contain kunkur, but do not resemble alluvial flats either in position, form, or elevation. The very convenient term *loess* has been applied to them, and the idea was suggested that such deposits might resemble those described by Richthofen as accumulations formed only by wind. The occasional erratic pebbles enclosed showed this view to be untenable.

Older silt.

The flanks of the hills near Khyrabád towards the Indus are covered with a mass of boulder and clay debris, sometimes gypseous, which I would assign to the post-tertiary sub-division; and close to Mári on the outer side of the hills, grey and reddish-yellow sands and clays form banks sloping towards the plains from their foot. These may either have been formed by the Indus floods, or may belong to the post-tertiary group.

Boulder clays.

The very strongly marked boulder-zone along the southern foot of the range (absent where the sands and clays just mentioned occur), is evidently due to the action of swollen torrents bearing down boulders from the hills. This zone has a varying width, generally greater where the number or size of the mountain streams is largest, and the fragments are, of course, those of the hardest varieties of the Salt Range rocks.

Boulder-zone.

It may commonly be observed that the streams from the hills crossing this zone terminate about the commencement of the finer alluvium, as if this covered a stratum of the coarser debris through which the water (when any exists in the channels) would be enabled to percolate more readily under ground than to find a way for itself across the slightly inclined or level plain. Unless this is the case, it seems almost unaccountable that the streams should not in many cases be able to reach the Jhelum river, only eight to twelve miles distant from the range, while several of them come from far behind the general escarpment.

Termination of southern streams.

On the north side of the range the most recent accumulations are usually either rain-wash, sandy mud, or clean grey sand; and the ground would appear to have been once less rugged, small, perched, isolated, remains of nearly level surfaces occurring here and there among the rain-worn '*khuddera*,' which presents throughout a most powerful example of the action of rain water.

North side of range.

In the lower portion of these '*khuddera*' streams, where their beds are wide and sandy, gold is sometimes washed for after rains; the places pointed out to me have been usually freshly formed banks, of coarse material, and the yield was said to average from two to four annas a day per man. Close to the range, however, it does not seem to be at all a thriving industrial pursuit. The tools, method of cradling, and treatment of the results with mercury, are fully detailed in Dr. Fleming's report at page 355.

Auriferous sands, &c.

Plateaux silt or wash.

On the different high plateaux where the angles of slope of the ground are lowest, a fine argillaceous silt washed from the neighbouring hills is deposited and forms some of the richest soil to be found near the range.

Calcareous tufa.

In very many places, and, of course, most frequently in the vicinity of the limestone rocks or on their surface, very large deposits of calcareous tufa occur enclosing *Planorbis* or *Helix*-like land and marsh shells, sometimes fragments of land-crabs, and often, as usual in such deposits, beautiful impressions of leaves.

Salts of lakes, 'kallar.'

The salts of the lakes and the '*kallar*' often found along streams, or on the ground on both sides of the range, being derived from efflorescence and collected by water in many cases, may also be included among the recent deposits.

Gypseous clay near Khyrábád.

South-west of Mári, on both sides of the stream which flows through an open hollow in the range near Khyrabád, are some large rounded or elongated hills of drab clay, extensively mingled with gypsum. They occur in the neighbourhood of seen or supposed faults, and if not a product of local streams which first deposited and then excavated a passage through them, they may be re-arranged portions of the red marl itself. It has been supposed that this gypsum here was the result of decomposition of limestone by sulphurous springs; if so, the action must have taken place to a very large extent.

The deposit bears no similarity to the Sabáthu gypsum of the northern side of the Potwár, and, on the whole, subterranean waters may have been its most likely source.

Supposed glacial period.

In a paper on the former extension of glaciers within the Kangra District, Mr. Theobald alludes to Dr. Verchere's notice of the erratic blocks north of the Salt Range; he assigns to these blocks a different

origin from that previously attributed to them, and connects them with the same glacial period which he believes to have left its traces in the Kangra valley.

The blocks alluded to are situated near Trápp or Tráb, a village eighteen miles distant from the nearest part of the Salt Range, and the only other erratics near the Salt Range which, so far as I am aware, could be referred to this supposed glacial period are the large one in the Khewra valley, another above Bághanwála, most probably derived from the boulder beds of group No. 10 in the series; or some crystalline blocks found at the foot of the escarpment between Jalálpur and Bághanwála. The power which transported these blocks and smaller erratics of the Salt Range, if it was not gravitation from the outcrops of the cretaceous (?) boulder beds,* aided by land-slip, may be perhaps referred to some form of ice flotation which seems the only agency adequate for the removal of such large blocks as some of those referred to.

The general series.—With regard to the general series now described, the sections nearest the Indus are known to be the fullest, and though local developments have been found to differ trans-Indus, the hills in that direction forming the continuation of the range still contain parts of the Salt Range series, and seem to be most largely formed of the mesozoic and tertiary rocks; portions of the older strata appearing in places.

Fullness of sections.

Although several of the cis-Indus groups have but a limited lateral extension, a general sequence throughout has been shown to exist, unaccompanied by marked or established unconformity up to the post-tertiary groups, yet characterised by several instances of transgressive deposi-

* Whatever may be the cause to which the present situations of these large transported blocks is due, it is equally difficult to account for their original position in the cretaceous conglomerates without the agency of ice. Mr. Theobald's discovery since the above was written, of a veritable ice-scratched boulder on the Salt Range, which he believes to have been derived from these boulder shales of the immediate locality, is very suggestive of ice action as the transporting power. In other parts of the country too, along the left bank of the Indus south of Attock, the foreign erratic blocks are too numerous and too large to be accounted for satisfactorily in any other way that I know of.

tion or overlap. Had some of these groups extended further, difficulties in the way of placing several of the others would have been removed.

The intervals left unrepresented, by the limited extension of certain of the groups, must be very considerable, and each case of the kind points to a break in the whole series similar to that contended for by Mr. Medlicott with respect to the nummulitic and newer tertiary boundary. It cannot be supposed, for instance, that while some causes limited the carboniferous rocks to one end of the range, carboniferous deposition was not going on somewhere else. If this limitation of deposition were observable only with regard to one formation, it would seem less strange, but there are here at least six or seven instances of circumscribed deposits of different geological ages, from possibly pre-silurian upwards. What the conditions were which thus confined the deposits of a geological system so extensive in time, with so few indications of even local unconformity, and restricted to the comparatively small area occupied by the Salt Range, is a difficulty which may be pointed out, but which I cannot at present explain.

Trans-Indus appearances of unconformity are stronger, but, so far as yet seen, are chiefly limited to the basal and upper boundaries of the cretaceous beds; the junction between the carboniferous limestone and tertiary sandstones, &c., of Káffir Kót (south), is perhaps also an instance in which the older rock has been denuded before the deposition of the newer formation.

The general absence of discordance in the series on this side of the Indus must be taken as evidence of enormously prolonged tranquillity, extending through all the epochs of palæozoic, mesozoic, and cænozoic time; and yet these tranquil conditions can have been but very local, for besides the unconformity just mentioned beyond the Indus, there is the most palpable discordance at Sirban Mountain in the Himalayan region between the infra-triassic beds and the underlying slates supposed to be silurian—a formation of which the Salt Range representative is perfectly conformable with the rest of the series.

PART II.

DETAILED DESCRIPTION.

SECTION I.—BAKRÁLA RIDGE.*

IN describing the local features observed at various points in the Salt Range, both the form of the ground and disposition of the rocks suggest that it will be best to commence to the east where the series is least full, passing on westward to its termination as the "Salt Range proper" at Mári on the Indus.

Situation.

Most people who have passed that way in the daytime may remember on the Grand Trunk Road, about twenty miles above Jhelum, a sharp dip into a river valley, and then a long ascent over intensely ravined ground, towards a higher grey rocky ridge which the road crosses, through a tortuous and not unpicturesque defile. This is the Bakrála ridge, taking its name from the pass, or a small village on its southern side. The ridge commences about four miles northward by east of the road, and may be said to terminate at Diljaba Mountain, having a length altogether of some thirty-three miles, and an average height of 1,200 to 1,500 feet above the lower ground in its neighbourhood; that lying to the north being some 400 or 500 feet higher than the open valley to the south.†

Bakrála Pass.

In the pass itself a fair section of the beds is seen, showing them to form an open, contorted, anticlinal curve, undulating a good deal within the pass, but dipping steeply at 40°, 50°, and 60°, to the north of west and south of east

* The Bakrála Pass lies a little way beyond the limits shown upon the map, but as the rocks form part of the older tertiary sandstones, &c., near the Salt Range, they are here described.

† Where not stated to be otherwise (as in this case), the heights given are those marked upon the Government maps showing altitudes above sea level.

respectively, at either end of this pass. Out in the plains to the north the dips become lower, and sometimes in a contrary direction, showing undulation of the beds; while on the Bakrála side they rise to vertical, having been apparently sharply folded and cut off by a fault along the base of the ridge. The rocks are grey and purplish sandstones, and red shales or clays, pseudo-conglomerates, and lumpy, slightly calcareous argillaceous bands, micaceous, grey and purplish soft shaly sandstones. These beds frequently contain a few indefinite plant impressions;* they all belong to the tertiary sandstone and clay group, and are chiefly remarkable for bearing a greater resemblance to "the Murree" beds than has been found to exist to the westward along the northern flanks of the Salt Range, in which region they do not seem to have existed.

Rocks.

This resemblance to the Murree beds is only to be observed along the ridge itself and among its lower beds ((*a*) of fig. 6, Plate X, (*b*) being Lower Siwaliks). But in the lower ground on both sides grey sandstones and brownish orange clays prevail, a zone of red clays with some sandstone beds dividing the two, or belonging more to the upper group. The brown or drab clays predominate just to the southward of the fault between the ridge and the village of Bakrála, and extend thence the whole way to the stream (a tributary of the Kahán) crossed here by the Trunk Road; they belong to the Upper Siwalik group, being the form which it assumes when conglomerates are few or absent. The anticlinal structure still characterises the ridge westwards, but is by no means regular, the beds being affected by many subordinate contortions.

At a distance of about three miles south-by-west from the village of Bakrála, and quite on the southern side of the ridge, some nummulitic

* A small fragment of bone was found in these beds above the road on the south-eastern side of the pass by Major M. G. Clerk of the N. S. Railway. Since this was obtained I have found a few remains of mammalian teeth and bones higher up on the ridge, and again within two miles to the south-west among the harder purple beds.

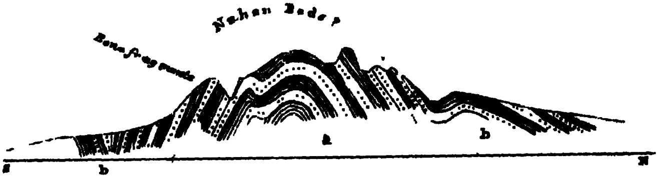

Fig. 6. Sketch Section Bakrala Pass

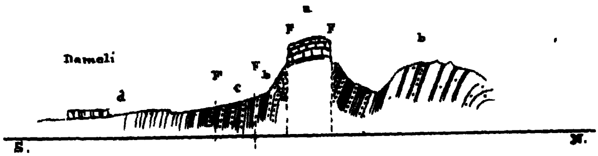

Fig. 7. Sketch Section across Nummulitic limestone near Domeli.

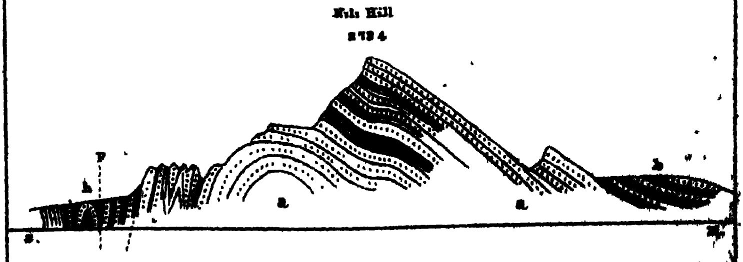

Fig. 8. Section across Bakrala Ridge W. by N. of Domeli.

limestone makes its appearance amongst local dislocations, and may be traced at intervals as far as the hill over Doméli. The ridge here becomes double and much wider, a long valley and other depressions dividing it midway longitudinally. The limestone occurs on the top of the southern elevations, being apparently brought up by a greatly compressed and broken anticlinal fold. It contains numerous casts of *Gastropoda* and some *Nummulites*. In a clunchy shale below are large and small *Ostrea*, and the lowest beds seen are of hard red ferruginous and spotted amygdaloidal-looking hæmatitic clay of lateritic aspect :* (See fig. 7 (Plate X), in which *a* is nummulitic limestone ; *b*, Náhan ; *c*, Lower Siwalik ; *d*, Upper Siwalik ; F, faults).

Nummulitic limestone.

The chief fracture which has brought these limestones, &c., into view is not very easily traceable among a number of smaller disturbances, but seems to have had an east and westerly direction, north of Doméli ; and the limestones, &c., do not continue in this direction across the river, on the banks of which that village is situated.

Faults.

The anticlinal arch has here lost a good deal of its symmetry and become normal, the angles to the north being low, while those to the south are very high, and the beds vertical, or closely crushed. A soft red zone also occurs at the outer foot of the hills on the Doméli side, and appears to occupy most of the escarpment of Nili hill near the centre of the ridge : (fig. 8, Plate X—*a*, Náhan ; *b*, Lower Siwalik ; F., fault).

Unsymmetrical anticlinal.

The tertiary sandstones and other beds of this part of the range are frequently covered by a white saline efflorescence ; and a considerable sulphurous and saline spring issuing from calcareous tufa is situated at the foot of the hill near

Saline efflorescence.
Brine spring.

---

* Probably representing the pisolitic zone of Mr. Medlicott's Jamu paper, *l. c. ante.*

Kalra.* The occurrence of this spring is very probably connected with the faulting which has allowed the nummulitic limestone to appear; and the sulphur may perhaps be taken up by the water from the pyritous shales which usually underlie this rock, although they do not appear in their ordinary place above the hæmatite nearer Doméli. Further to the south-west the ridge maintains very much the same character, lower angles of inclination being observed on its northern side, and higher ones to the southward; the beds also on each side are softer than those of which the ridge itself is composed, and more level ground than the "*Khuddera*" along the hill-foot has formerly existed, as is shown by numerous patches of the older surface not removed by denudation.

Country on each side

The country on each side of the ridge, particularly to the south, is covered by immense deposits, chiefly of clay, the results of atmospheric denudation; but the numerous ravines, streams, and higher parts of the ground occasionally expose the soft Lower Siwalik beds of the tertiary series.

Ghoragali.

Where the Bunhár river cuts through this Bakrála ridge at the gorge of Ghoragali, the rocks have suffered more than usual disturbance and fracture. Thick, soft grey sandstones with occasional pebbles are seen beneath the superficial deposits in the river banks at a mile or so from the northern entrance to the gorges, dipping to the west-by-north at 10°; these are faulted against greenish and brown sandstones and drab or reddish clays, which are folded, vertical, and compressed, and brought by another fault against a strong vertical rib of whitish nummulitic limestone; the latter runs up the right side of the gorge, widening, as it goes, to join the limestone patch capping Diljaba mountain. At a little distance on the left side of the gorge this rib of limestone is cut out by other fractures, and disappears. Close to the limestone, on its southern side, the grey sandstones and red clays are much crushed, dipping towards it at 45° and

* This spring is described under the heading "Springs," Part I, p. 47.

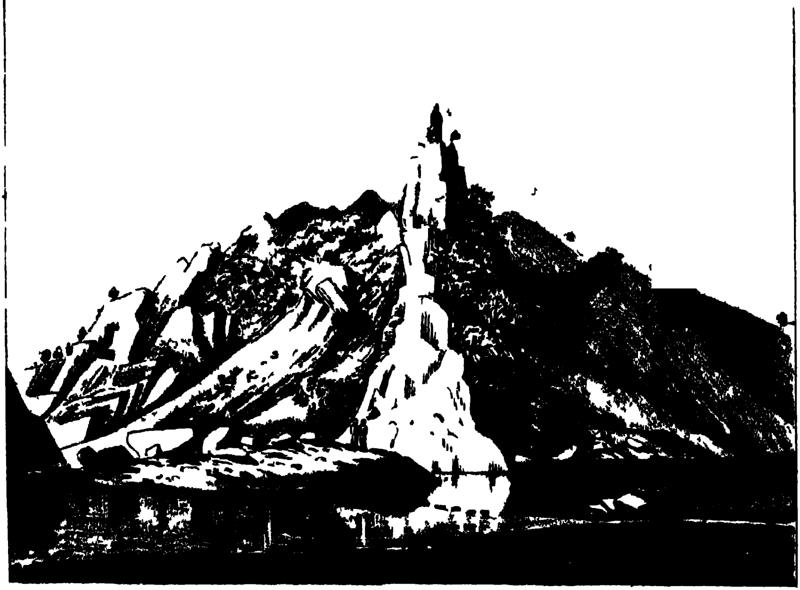

Fig 9 Rib of Nummulitic limestone in Ghoragally Pass

Tertiary sandstones on both sides

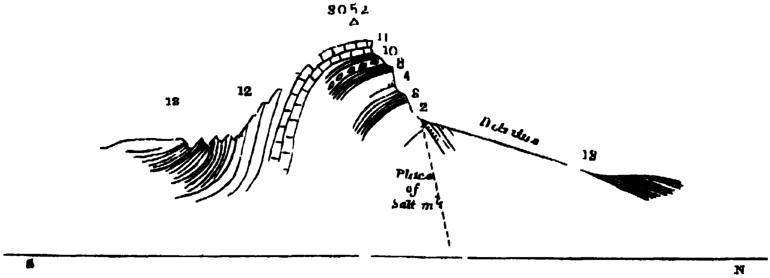

Fig 10 Across Diljaba mountain

2 Purple sandstone 3 Silurian 4 Magnesian sandstone 8 Salt crystal zone 10 Olive group

11 Nummulitic limestone 12 Nahan 13 Lower Siwalik

higher angles; but a little further away, assuming the usually high dips of the southern side of the ridge. These sandstones become conglomeratic with silicious and limestone pebbles, and are overlaid by a broad belt of bright red clays with fewer sandstone bands. (See fig. 9, Pl. XI.)

Diljaba.

Diljaba mountain, the south-western termination of the Bakrála ridge, is much more lofty than any other portion of it, having a summit elevation of three thousand and fifty-two feet. From the abruptness of its north-west scarp and the occurrence of some of the tertiary sandstones close beneath this, the mountain appears to have been separated from the rocks of the low country upon that side by a continuation of the fracture or fractures seen in the Ghoragali gorge. Having passed the thick covering of detritus close to the foot of the escarpment, the dull reddish-purple sandstones of the group No. 2 in the table are exposed. Over these comes the dark shaly zone No. 3, surmounted by the strong magnesian sandstone group, overlying which is the red and greenish, flaggy, "salt-pseudomorph zone." This is succeeded by the conglomeratic beds and sandstones of the "olive group," here containing the remains of *Ostreæ*, and passing beneath the lower beds of the nummulitic limestone, the talus of which probably conceals the coaly shales frequently occurring at that horizon. The stronger beds form cliff-benches, and the ground is in places covered with *sunhetta* jungle, so that the section is obscured, or is concealed by detrital accumulations on the benches, but can still be made out. The nummulitic limestone, just on the ridge, is flat or gently undulating, averaging from fifty to a hundred feet in thickness; but almost immediately commences to descend the south-eastern slopes of the hill with a rapidly increasing dip.

South-eastern slopes.

The very summit is formed of the lowest beds of the tertiary sandstone lying conformably upon the limestone and stretching up the steep south-eastern sides of the mountain in great sheets, which, placed almost on edge, form ground too steep for cattle or almost for goats to frequent, and consequently a favourite haunt for the "Ooriar," "Metoo,"

or wild sheep (*Ovis cycloceros*) of these hills. The beds which more immediately overlie the limestone are of grey sandstone, lumpy shales, and pseudo-conglomerate. Some of the sandstones are very coarse, and in one of these a short bone, like the humerus of a reptile, was found, which broke, however, in the effort to remove it. Overlying these and reaching along the base of the hill is the strong red clay zone, before alluded to, succeeded by soft grey Siwalik sandstones and light brown clays (see fig. 10, Pl. XI).

Similarity to Murree beds.

The most interesting circumstance connected with this Bakrála ridge is the identity some of its beds present to the Murree group, and in consequence to the older tertiary rocks of the Sub-Himalayan series, while this identity, together with the occurrence of bones, bone fragments, and *Mastodon* teeth, seems to present in one group the characteristics both of the lower tertiary and the Siwalik divisions.

SECTION II.—MOUNT TILLA RIDGE.

Before described.

A short paper has already appeared in the Records of the Geological Survey* explanatory of the geology of Mount Tilla; still, as the ridge claims a place among the connecting links between the Salt Range and the Himalaya, it must be noticed.

Eastern termination.

The eastern termination of the Tilla Ridge just crosses the Grand Trunk Road, from which the hill itself may be plainly seen, looking all the finer because it is viewed endways and full advantage given to its height of 3,242 feet above the sea. The ridge has a length of 26 miles, but the western part only is lofty, a few bungalows upon its summit near the Pír (or sacred locality of the natives), with its fine old tank and temples, surrounded by various trees (among which a deodar is conspicuous), forming a small but picturesque sanatarium for Jhelum station.

* Records, Geol. Survey of India, Vol. III, pt. IV, p. 81.

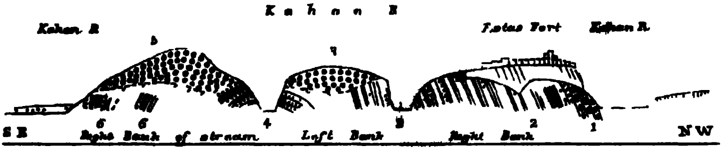

Fig 11 Section in Kahan River Gorge Rotas 9 miles in length

1, Conglomerates Sandy beds and Clays 2, Gray sandstone and brown Clays 3, Conglomerate and its detritus 4, Gray Sandstones and Clays 5 Conglomerate (Post tertiary) 6 Sandstones &c

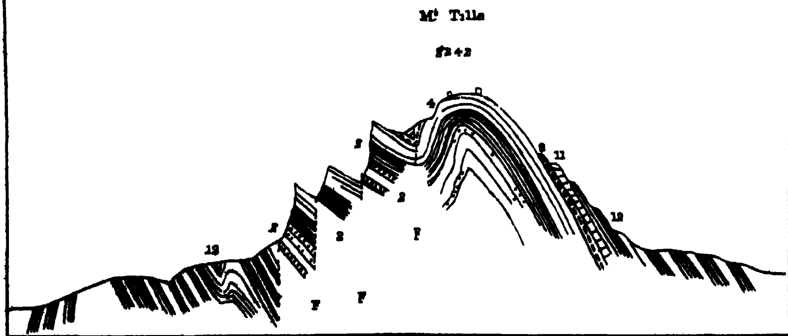

Fig 12 Section over Mt Tilla

2, Purple Sandstone 3, Silurian 4 Magnesian Sandstone 8 Trias ? 11, Nummulitic Limestone 12, Nahan 13 Lower Siwalik F Fault

Round the termination of the ridge to the eastward is the low country and alluvium of the Jhelum, which, following the course of that river, extends along the southern side of the ridge past the wide sandy bed of the Bunhár river, as far as the neighbourhood of Dhárapur. Embracing the low extremity of the ridge, and rising from this alluvium, is a crescent-shaped belt of low pebble-covered hills, derived from the waste of the incoherent Upper Siwalik conglomerate rocks. The pebbles in these consist principally of quartzose grit with fragments of other metamorphic or crystalline rocks, and the detritus, apparently of these beds, is found as a re-arranged, unconformable, post-tertiary deposit, resting upon the flanks of the ridge near Rotás. Where such beds as these occur in open ground, it is very difficult to see their relations; they weather down into beach-like slopes, covering everything else from view, and when occasional cliff or bank sections occur and total discordance can be seen, the re-arranged materials simulate the original structure of the beds so closely that appearances cannot always be trusted.* The horse-shoe arrangement of the pebbly ground, however, coincides with an anticlinal structure seen at Rotás gorge in the tertiary sandstones, &c., and conglomerate bands are occasionally found intercalated with the latter beds in the neighbourhood.

Alluvium and conglomeratic zone.

The gorge of the Kahán river, near the old fortress of Rotás, shows both these and the unconformable post-tertiary conglomerates, as well as the subjacent tertiary sandstone and clay beds (see fig. 11, Pl. XII). The conglomerates are much more frequent over the country beyond the north-east bank of the river; while on the opposite side of the stream they

Rotás gorge.

* Upper Siwalik conglomerates and their debris, formed more largely or exclusively of rounded syenite, quartzite, and other crystalline fragments, are widely distributed along the Indus, beyond which river, on the track from Kálabágh to Shakardara, they are seen to be perfectly conformable to the upper grey tertiary sandstones, &c.,—single pebbles and layers of pebbles first appearing, afterwards becoming more numerous, till at last enormous masses of conglomerate supervene.

extend but a short way, the mass of these beds having been removed or never deposited.

From Rotás towards Tilla.

From Rotás to Mount Tilla the Upper Siwalik beds are all on edge, running in a south-westerly direction either straight for the hill, or so as to pass along its southern side, occupying a width of about three miles. In these rocks contortions may exist, but the tops of the arches having been removed by denudation, the structure of the ground is obscured; the main anticlinal, however, as at Rotás, lies well to the south-east side of the broken rising ground. In a southerly direction the country near the hills is covered by debris, apparently derived from very soft underlying rocks in which clays predominate. Just along the foot of the tertiary hills are conglomeratic beds with limestone pebbles, pseudo-conglomeratic and grey sandstones, with light brown clays. Ascending the slopes, purple and red clays alternate with grey soft sandstones; while about the region of the anticlinal, and on the north-eastern side of this, brownish clays, and soft, coarse and fine sandstones, with some gravelly beds, again appear. Near the middle of the ridge, where the road from Jhelum to Mount Tilla meets the old one from Rotás, a zone of ossiferous sandstones is intercalated with the brownish clays and sandstones. Bone fragments are locally numerous in this, but as they are embedded in a very fragmentary state, the finding of good specimens must be quite accidental.

Bone beds.

Thickness.

The thickness of the tertiary beds of this ridge and its neighbourhood must be great, but calculations regarding it are affected by uncertainty as to the existence of compressed and concealed contortions. Beneath the Rotás fort these beds dip to the north-west steadily for more than a mile at 60° and 70°, giving a thickness of 4,700 to 5,000 feet. In the event of plications not occurring, that thickness might be fairly doubled, while the softer beds beyond the ridge may be at least 5,000 feet more. Hence 10,000 feet does not seem too large an estimate for this portion of the tertiary rocks.

Mount Tilla.

At a distance of eight miles from Rotás, Mount Tilla commences to rise above the lower part of the ridge. Here older rocks are brought against the beds just now described by a fault or faults, the beds of different age in contact being greatly crushed, and some of the red tertiary clays in the neighbourhood have the rather unusual character in this part of the country of being gypseous. The hill being high and the southern escarpment bold, instructive sections appear almost everywhere upon it, and the geological structure is clear; but the series is repeated in great part twice, if not three times, by slips or faults parallel to the main dislocation (see fig. 12, Pl. XII). Along the south-eastern base of the hill, the ground, there tolerably high, shows the grey and brownish or red portion of the tertiary beds, generally nearly vertical, with an inclination towards the hill, but sometimes folded. The lowest rocks appearing along the fault are the earthy basal portion of the purple sandstone group No. 2, with here and there possibly the top of the red marl of No. 1, which shows itself further to the west; but this is so much of the colour of the red tertiary clays, observed to be gypseous near Mogli village, that it is difficult to distinguish between them.

Faults.

Cliffs.

Thin purple sandstones, the silurian zone, and overlying magnesian sandstones, &c., form the cliffs, above which the supposed trias group, No. 8, with salt-pseudomorphs, appears, and the summit is formed by an anticlinal roll in the hard magnesian group. The red zone No. 8, again showing itself on the steep bedding-slope of the northern side of the mountain, is followed by a thin and uncertain representative of the nummulitic limestone, with some shales below it here and there; above this come the usual grey and greenish lower tertiary sandstones and reddish clays. The red clays here (as elsewhere), becoming locally prevalent, range themselves in a zone along the north base of the hill, beneath the soft grey sandstones and brown or orange clays forming the Lower Siwalik group. Remnants of the nummulitic limestone also occur near the summit of the hill.

Series.

Thickness.

The following is the estimated thickness of each of the groups:—

	Feet.
Siwalik sandstones and clays, grey, brown, and red zones ...	1,200
Náhan zone	800
Nummulitic limestone	15 to 30
Salt-pseudomorph zone, variable	30 to 20
Magnesian sandstone	150 to 200
Black shaly zone (silurian)	100 to 180
Purple sandstone group	170 to 250
Red salt-marl with gypsum	50 and upwards.

Magnesian sandstone, &c.

Immediately to the south-westward of the summit two deep ravines expose sections in the beds as low down as the purple sandstone, the magnesian sandstone forming a narrow edge above a vertical precipice formed by this and the underlying rocks. The same group undulates over a large lobe of the mountain, between some ravines and the more open glen north of Nára, edged by precipices. At the base of these the salt-marl makes its appearance, while from their crest the steep north-western slopes of the mountain commence. The salt marl here is, as usual, accompanied by gypsum and white calcareous bands (probably magnesian limestone layers), which contain very perfect casts of hopper-crystals of salt.* These are rather numerous close to the Mount Tilla experimental shaft, sunk in this gypsum and marl to seek the salt which ought to occur beneath it. The site chosen for this shaft or driving seems to coincide exactly with the run of a fault or extensive slip. Appearances outside would lead to the expectation that the solid rock should be found much within the length the driving has been carried to, instead of which the ground it has passed through exhibits a most heterogeneous accumulation of detrital fragments of the local rocks. From this fact it would seem that the line of division between a great subsided mass

Nára glen.

Salt marl.

* First observed by Dr. Warth.

of the magnesian sandstone and the main mountain, must "hade" or "hang" to the north; but much confidence cannot be felt in speaking of debris, which is nearly all that the driving exposes. This debris can hardly extend much further, and it is understood the driving is to be carried through it, into the rocks of the mountain, where its course towards the position of the salt will be decided by the lie of the beds. As usual in mining operations, where the extension of the beds is not known, nothing but a trial could prove the fact of the salt being present here or not; but the probabilities are all in favour of its existence.* Salt-springs occur, perhaps on the same horizon, at the edge of the Bunhár river near Pind-Sevíka to the south-westward, and also near the north-eastern termination of the older groups of Mount Tilla not far from Bangiál, at a place called Lunáda. The occurrence of these brine-springs in both places is probably connected with that of the main Tilla Fault.

Boulder zone.

Beneath the precipices over Nára glen may be observed the first indications of the boulder zone which borders the Salt Range along its southern side.

South-western extension of mountain.

The south-western extension of the mountain beyond these cliffs, though high, is less so than the more faulted portion, but still it has summits of 2,304 and 2,004 feet. An open, though incomplete, anticlinal structure occurs here, the south-eastern side of which has suffered dislocation and erosion; and the whole mountain having a somewhat broader base, the foundations of the wide and undulating arch occupy a larger area. The salt-marl is just seen at the base of the escarpment, the purple sandstone forms the body of the cliffs, the dark shaly silurian zone accompanying it, and the hard magnesian sandstone forms rough undulating plateau ground, overlaid by the salt-pseudomorph band, here locally thick. The Náhan sandstone-and-clay series caps the mountain and contains quantities

* A special examination of this locality was made and the results communicated to the Inland Revenue Department in April 1874.

of silicious fossil exogenous wood, a narrow zone of nummulitic limestone being just traceable beneath it. These upper beds turn downwards on the steep north-western mountain slope and the red earthy zone, and softer sandstones with brownish clays occupy the lowest ground in this direction, which is, however, much cut up by *khudders* and ravines, and rendered more rugged than it would otherwise be by reason of the steep angles at which the beds pass downwards.

Curve at west end of ridge.

At the western end of the ridge all the beds are suddenly bent down and locally faulted or fractured, describing in plan the half of a semicircular arch with a radius of more than two miles, the other half being apparently cut off by the Pind-Sevíka portion of the Tilla fault. This arrangement of the beds is well shown by the topographical ornament upon the one-inch map, and the tertiary beds roll over to so great a degree that they often lose their outward inclination and sometimes appear to dip towards the hill. With this structure it is difficult to conceive much internal or local contortion of the beds, and in the absence thereof, this portion of the tertiary sandstones and clays, including the Náhan beds, must have a thickness of fully a mile and a half, or seven thousand nine hundred and twenty feet.

Remnants of old plains.

Here and along the north-western base of Mount Tilla the patches of ancient flat surfaces before alluded to are not uncommon, and masses of recent conglomerate appear to have once filled the gorge at Pind-Sevíka. Between this place, also, and Ghoragali Pass, the Siwalik beds appear to be auriferous, gold being found in the sand of the Bunhár river, but not in larger quantity than usual.

Gold.

Epitome.

With the exception of one group, the "olive group," or "cretaceous," and some shales below the nummulitic limestone, it will be seen that Mount Tilla forms an epitome of the whole of the stratigraphic geology of the Eastern Salt Range.

Section III.—Chambal Mountain, East.

Chambal Mountain, East.

There are two Chambal mountains, one west of Jutána and the other north of Jalálpur. This latter mountain presents much peculiarity as to structure. In its vicinity great fractures occur, and it appears to be itself a result of extreme and complicated dislocation, the ordinary anticlinal and synclinal disturbance being interrupted by faults.

Peculiar position of strata and dislocation.

The disturbance of Mount Tilla is great; its dislocation and contortion, however, appear natural and intelligible, but having crossed the Tilla fault, the strike of the strata, their inclinations, and positions are discontinuous and discordant, the later tertiary beds striking so as to run against the earliest rock of the series, the red salt marl; and the only remnants of symmetry left being in the dips of these newer beds, those of the two mountains tending to form opposite sides of a broken synclinal valley, in which rest the broad quicksands of the Bunhár river.

Pind-Sevíka gorge.

One spot where extreme results of dislocation can be seen is the lowest and last, the Pind-Sevíka gorge of the Bunhár river; on the Tilla side of this are the undulating, nearly horizontal, but depressed, older beds of the whole series, with a little of the salt-marl at their very base (from whence brine-springs issue); while on the Chambal side the purple sandstones, silurian zone, and magnesian sandstone incline at an angle of 45° to the north-east, being apparently checked by a fault; the red zone and overlying beds of the upper tertiary series dip in the same direction at 50°, 60°, and 70°, in such a way that their strike, if prolonged, must abut against the older rocks of Tilla.

North of Jalálpur.

Again to the north of Jalálpur the whole series is reduced to the similitude of a gigantic breccia, in each fragment of which several groups are included, the

disturbance first met with north of that town being so complex that the one-inch map fails to show it correctly.

Chambal scarp.

The scarped side of this Chambal Mountain, unlike other similar features in the vicinity, is presented to the westward, and bears the nearest analogy to a step-fault on an enormous scale, repeating the features found in the scarp from Jalálpur to Jutána. The escarpment is high and steep, rising over the village of Chanod (or Chanad as spelled upon the map) to 2,290 feet above sea level. The base of the cliff is covered with a deep talus of debris and travertine conglomerate, but the salt-marl and gypsum can be seen in many places along its lower part; and at one place, not far from the village named, a subsided mass shows the whole of the purple sandstone group capped by the shaly silurian band.

Chambal scarp continued.

In the escarpment itself both the purple sandstone and the shaly band re-appear and are continuous along it, but the magnesian sandstone is only slightly represented, its development increasing to the northward. The red zone with salt pseudomorphs is absent, and the lower beds of the tertiary sandstone and clay series rest directly (where the succession is complete) on the representative of the magnesian limestone or on the underlying silurian band, without the intervention of either the olive series or the nummulitic limestone. Three characteristic groups of the eastern succession are thus missing, and among those that are present any want of development seems to have been the result of thinning out, and not of pre-tertiary denudation having removed any portion of them; so that the series, limited as it is, still appears to be quite conformable.

Tertiary sandstones, &c.

From the crest of the hill the tertiary sandstones, &c., curve downwards towards the east at angles of 50° and 60°, grey sandstones and the reddish clays rapidly alternating as the beds succeed each other, the clays predominating in a soft zone worn away to form the valley traversed by the Jhelum road, and following the curve of the hill. An escarpment facing the moun-

tain borders this valley or pass, and is formed by some stronger bands of sandstone, etc., the dips being still high, and, near the village of Núrpur vertical, giving a thickness of more than a mile. Further eastward soft grey sandstones and light brownish Siwalik clays with conglomerate bands undulate over an intricate and deeply-ravined mass of lower hills towards Dárapur, some of the sandstone beds being extremely soft and weathering down to sand heaps. These upper beds form a very wide arch with gentle inclinations, except on the banks of the Jhelum, where the dips are generally high. The series is as follows:—

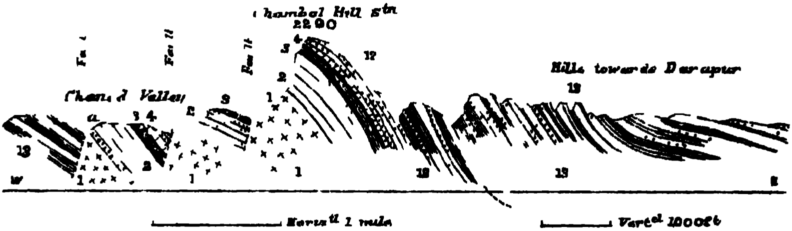

Fig 13. Section over Chambal Hill (East).
a, Dolomite bed in Salt-marl.

			Feet.
Siwalik No. 13	...	Grey sandstones, very friable, and light brown marly clays; maximum apparent thickness, which may be much below the real amount	5,500
		Red zone, chiefly clays	1,500
Náhan No. 12	...	Lower sandstone, etc.	500
Nos. 9, 10, 11	...	Nummulitic limestone / Olive group / Salt-pseudomorph zone — ABSENT	0
Palæozoic	...	4. Magnesian sandstone	50 to 0
		3. Dark shaly band (Silurian)	150 to 200
		2. Purple sandstone	500
		1. Red gypseous marl	?

Rocks of the dislocated ground.

In the dislocated ground between Jalálpur and Vang, the village of Chanod is situated near the middle of a faulted portion of the rocks, comprising several of the local groups. The stream below the village shows the red salt

marl, faulted against the upper tertiary beds, and just at the top of the marls there occurs a massive band of pale, whitish grey dolomite, in places reddish and containing cherty nodules; hard white granular bands occur in it, and it has all the aspect of solid grey limestone, and weathers in the same form, but does not effervesce with acid. It is well seen in a low hill at the southern edge of the plain of Chanod, where its thickness seems to vary from one hundred to one hundred and eighty feet. The same rock occurs again, brecciated, in faulted ground amongst the red marl, at the base of the Chambal scarp west-by-south from the same village, these being the only instances in which this bed has been found, along the whole range.

Dolomite in salt-marl

The dolomite is overlaid by some four hundred and eighty feet of the purple sandstone group, the beds becoming calcareous as they ascend, and including pale purple and orange, vesicular and calcareous bands with green specks, some slightly micaceous beds being more calcareous than others. These are succeeded by the dark shaly silurian band, here apparently thinner than usual, and resting upon it are about forty feet of the compact light semi-calcareous sandstones, of the magnesian sandstone group, passing apparently beneath some portion of the tertiary sandstones not well seen at the surface.

Series above.

Where the tertiary beds rest upon the silurian band at the south end of the Chambal hill, the upper fifty feet of the purple sandstone group below this band is very soft and of a whitish colour; the outcrop of the silurian shales is but ninety paces across, with a southerly dip of 50°; and the Náhan sandstones resting on them form ground like that on the south side of Diljaba, their steeply sloping beds ascending to various heights upon the mountain side.

Junction of tertiary and silurian.

In the neighbourhood of Jalálpur, for a mile to the westward of the town, and for several miles to the eastward, the tertiary sandstones, conglomerates, and clays dip at

Jalálpur.

angles of 40°, 50°, and 55° to the south,* and form most rugged hilly ground. Up the stream from this town the steady southerly dip of 35° and 40° does not long continue, the beds soon commence to undulate and are crossed by a line of intense crushing and faulting: for a width of one hundred yards the rocks are much mixed, fragmentary portions of different groups being brought together, squeezed, slipped, and wedged in amongst each other, the most prominent being the purple sandstone and marls and gypsum of the salt series; and the softer tertiary clays show saline efflorescence. This line of crushing and fault,

Faulting.

bearing south-west, crosses from the southern end of the Chambal scarp, so as to cut off the Mangaldeo end of the Jutána scarp and bring the older rocks against the tertiary beds, close to a temple above the village of Dheri. Eight or ten other faults occur in the vicinity of the "divide" or watershed between the Bunhár and Jhelum rivers here, nearly all of them bringing groups of most dissimilar situation in the series into contact.

Khárián hills.

The Khárián or Pabbi ridge on the south bank of the Jhelum, forming a sort of continuation of the Chambal hills, is principally composed of the soft Upper Siwalik beds, and, receding from the stream where crossed by the Grand Trunk

Continuation of Chambal.

Road, is laid open by the deep cuttings for the Northern State Railway. The sandstones are all of soft texture, but are harder inside, and both these and the thick bands of warm orange or light brownish red clay crumble away and wear into deep ruts under the action of the rain, though "so tough and coherent as to have required blasting in making the cuttings." The beds form a low open anticlinal arch.

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* The neighbourhood of Jalálpur seems to have furnished some good reptilian and other fossils during the survey of Dr. Fleming, &c. Although sought for, these highly fossiliferous beds have escaped my notice.

SECTION IV.—JALÁLPUR TO JUTÁNA.

Escarpment.

The well-marked escarpment from Jálalpur to Jutána exposes very much the same section as Mount Tilla. The salt marl shows a thickness of thirty to fifty feet beneath the Jalálpur end of the ridge, and on the northern side a thin representative of the salt-pseudomorph zone appears in its proper place as regards the underlying beds, but overlaid by the tertiary sandstones, etc., to the exclusion of the nummulitic limestone and olive groups.

Thil and to the west.

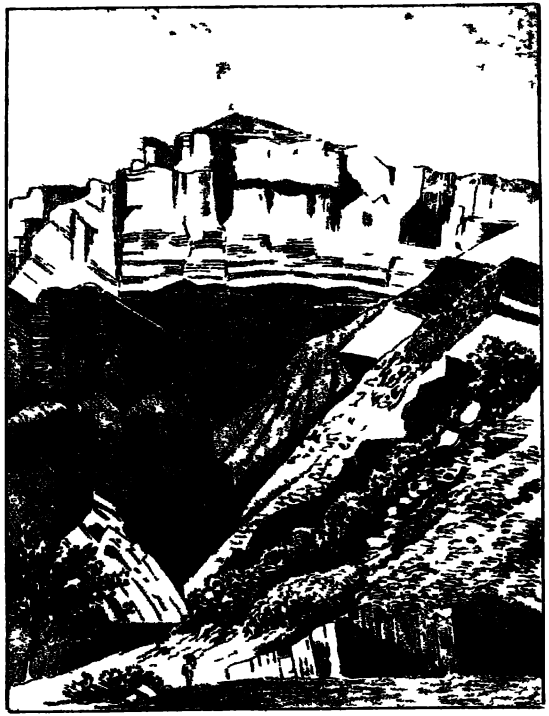
The beds forming the ridge have steady dips of 30°, 40°, and 50° to the north-east, with a tendency to flatten on the outcrop, as at Thil, a couple of miles beyond which place a thin yellowish calcareous marly bed represents the nummulitic limestone. The red salt-marl is not known here, but a portion of it may be concealed beneath the debris immediately at the base of the escarpment. Above this comes the purple sandstone, well developed and succeeded by a talus of the dark shaly silurian zone, then the strong beds of the magnesian sandstone; then the red salt-crystal-cast zone, thicker than before; the nummulitic band, the grey, gravelly, and pseudo-conglomeratic tertiary sandstones on the northern slope; the tertiary red clay zone at its foot, and the brown clay and grey sandstone beds of the Siwalik groups down in the Bunhár valley between this and Mount Tilla. (See section, fig. 16, Pl. XIV.)

In this neighbourhood, at a considerable height upon the talus at the southern side of the ridge, a kind of drift or rain-wash contains numbers of small crystalline and metamorphic boulders, the source of which is rather mysterious, seeing that the olive group, with its clay-shale conglomerates consisting so largely of these fragments, is not represented in the local section. The Jhelum river passes through a country in which conglomerates of the tertiary series contain numbers of the same or similar crystalline boulders, and their presence here may indicate their having been transported by this river in former times.

J Schaumburg Lith

2 Purple Sandstone 3 Silurian 4 Magnesian Sandstone 8 Salt Pseudomorph zone

Fig 14 Cliffs from above



2 Purple Sandstone 3 Silurian 4 Magnesian Sandstone 8 Salt crystal zone

Fig 17 Cliffs from below

CLIFFS NEAR BHAGANWALA

Westwards towards Bhágauwála the ridge grows wider, the flattening of the beds on the top of it more decided, though undulating, and the strike of the tertiary beds trends off to the northwards to enfold the termination of the Eastern Plateau. In this locality, too, the olive sandstones and conglomerates of the cretaceous zone No. 10 begin to appear.

Towards Bhágauwála.

The face of the escarpment close to Bhágauwála on the left-hand side of the glen has been fractured, or slippage has taken place, so as to present the appearance of a double set of lower beds, the fractures and their results being of the same character, but on a smaller scale, than those of the Tilla and Chambal scarps already mentioned. Within the little glen at Bhágauwála the rocks are much disturbed, the lower earthy part of the purple series being seen, and just the top of the gypseous red marl, here not sufficiently saline to impregnate a delicious stream of fresh water flowing through the ravine. The banks of this stream are lined with water-cresses, and highly coloured (blue and pink) crustaceans inhabit the water.

Bhágauwála.

Two paths lead from this gorge up the precipices to more undulating ground above. The best of these passes by a small but picturesque ruin perched upon the cliff edge, and the other, which is by no means safe or pleasant, ascends obliquely to the eastward the cliff formed by the magnesian sandstone on the northern side of a deep ravine entering behind the outer hills. The path leads to the bed of a stream, which must form a fine waterfall as it descends over the outcrop. It was dry when visited; but such is the permeable, jointed nature of the strong magnesian sandstone group, that a quantity of water (having evidently percolated from the stream bed above) issued from the lower portion of the cliff over which the river falls when the stream is full. The undulating ground above the cliffs is occupied by the red clays, mottled with green, and red stained flags, of the salt-pseudomorph group, from beneath which a lofty bedding-slope of the magnesian sandstone rises at angles of 30° and 40°. (See fig. 14, Pl. XIII.)

The olive group is apparently only locally developed and not thick in the neighbourhood, yet a large syenitic block, or boulder, supposed to have come from it, which was observed in the stream bed above the fall, measured six feet four inches in length.

Large erratic block.

Following the tributaries of this stream north-eastwards, the head of a ravine is reached, which leads into the Bunhár valley near Kotal Kund. High, tertiary sandstone and conglomerate hills rise on either side, their beds dipping to the north-north-east at 50° and 60°, and just below these rocks is a band of nummulitic limestone overlying dark coaly shales, with a bed of good coal three feet six inches thick. Underneath it some sandstone occurs, and then a band of bluish grey shale, which rests directly upon the red salt-crystal-cast zone. This is the Bhágauwála coal locality, the "mines" being represented by a few small excavations in the bank at the side of the stream.

Coal locality.

The ground is bad and the ravine steep and so narrow that a fallen mass from the limestone had almost blocked it up; but the flood water had found a passage, through which the tape was carried, partly beside and partly beneath the block. The following is the section measured at this place, which is about two miles in a straight line north-east of Bhágauwála. (See fig. 15, Pl. XIV.)

		Ft	In
Marái Tertiary Sandstone.	18. Gray pseudo-conglomeratic sandstone, dip 60°—70°	21	6
	17. Conglomerate	2	6
	16. Sandstone ...	4	0
	15. Conglomerate	6	3
	14. Sandstone ...	6	0
	13. Conglomerate	3	0
	12. Sandstone ...	18	0
	11. Pseudo-conglomeratic shale	4	6
Nummulitic.	10. White and brown variegated impure limestone	15	0
	9. Shaly band ...	1	0
	8. Lumpy limestone, dip 45° (somewhat slipped?)	27	0
	7. Yellow fossiliferous nummulitic limestone	11	0
	6. Black shale ...	3	0
	5. Coal shale including 3 feet 6 inches coal	14	0
	4. Gray lumpy sandstone ...	2	0
	3. White ferruginous sandstone, coarse quartz grains and unctuous white clay matrix, with black shaly and carbonaceous veins, and strings, and delicate purple and green earthy layers above, conglomeratic at base	21	0

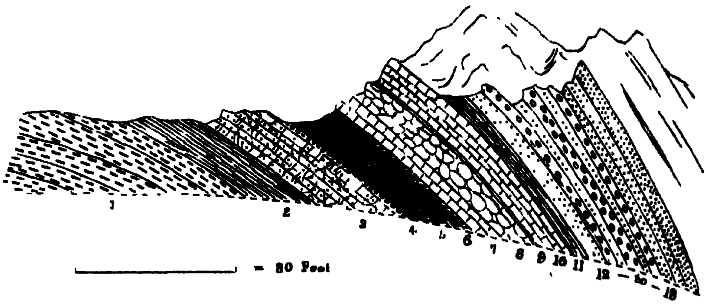


Fig 15 Section across Bhaganwala Coal bed

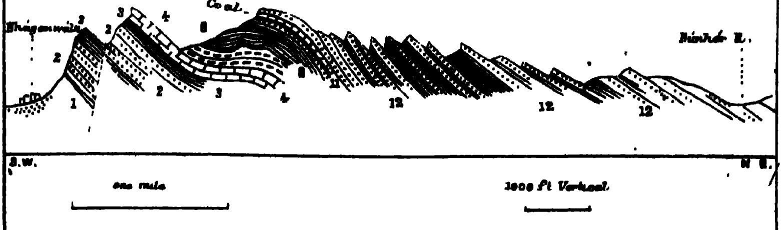


Fig. 16 Section from Bhaganwala to near Kotalkund.

		Ft.	In.
Trias ?	2. Bluish gray shale, red blotches below	20	0
	1. Red and green variegated clay-shale, measured up to 420 feet, but partly undulating	390	0
		437	9

The coal of this locality will be found mentioned at page 8 of Dr. Oldham's memorandum already alluded to, being the first that he notices. It is traceable for about two miles altogether, or less, and with the including beds forms an open curve bulging towards the north. The associated shales and the coal itself are pyritous, causing the coal to take fire spontaneously.

Nummulitic limestone thickening.

In the section from Bhágganwála to near Kotal Kund (fig. 16, Pl. XIV),* the nummulitic limestone has already gained considerably in bulk and exhibits its two characteristics, of solid and lumpy-beds; the latter having much the appearance of conglomerates in consequence of the nodular portions being surrounded by softer marly rock, which weathers more readily and is often crowded with small nummulites. There is here certainly no stratigraphic indication that any unconformity exists between the nummulitic and succeeding beds. Nor is there any sign of unconformity below the nummulitic group; the gray and white sandstone with carbonaceous streaks occurs in other places with the same relations of paralellism to the overlying and underlying rocks, though the "olive group" is entirely absent. The gray shale (No. 2, at top of page) appears to form a part of the underlying beds of group No. 8.

No unconformity.

Local thickness of salt pseudomorph band.

Group No. 8 (Nos. 1 and 2 in this measured section). has greatly increased in thickness, chiefly by the appearance of a quantity of shales and clays in its upper part. In this place, after making large deductions from the measurements,

* 1.—Salt marl. 2.—Purple sandstone. 3.—Dark shaly band (silurian)? 4.—Magnesian sandstone group. 8.—Salt-crystal zone. 11.—Nummulitic limestone and coal. 12.—Tertiary sandstones, &c.

on account of undulation, a thickness is found which cannot fall far short of 500 feet. The other groups have their usual dimensions; the magnesian sandstone from 150 to 200 feet, the silurian shales 150 to 180 feet, and the purple sandstone from 400 to 500; its lower 70 feet being flaggy and shaly and passing downwards into purple marl.

Tertiary sandstones, &c.

The tertiary sandstones, &c., dip at high angles, and must be very thick, the quantity, however, shown in Fig. 15 appearing greater in consequence of the section crossing the line of dip obliquely. The steep dips are confined to the northern slope of the ridge; having gained the summits of which, the beds bend over and become horizontal, their outcrop and that of the nummulitic limestone terminating in a scarp only 150 or 200 feet deep. Where the ground falls rapidly, these rocks are cut into by numerous deep ravines.

Escarpment.

The main escarpment about Bháganwála is a good deal broken, massive portions of the cliffs having fallen entirely or partially slipped from above. (See fig. 17, Pl. XIII.)

Westward of Bhágan-wála.

Westward of Bháganwála the ridge rapidly increases in width as it joins the Eastern Plateau of the range. The escarpment still continues bold and marked towards Jutána; the purple sandstones and dark shaly silurian zone being everywhere capped by the magnesian sandstone which forms the

Series.

cliffs along this feature. The ground above undulates greatly, much of it being covered with the bright red salt-pseudomorph group, and some higher hills are formed of the nummulitic limestone, here more than a hundred feet in thickness, while to the northwards the highest part of this undulating country exposes the lower tertiary sandstones, &c., in the neigh-

Tertiary sandstones, &c.

bourhood of Ara. To the east of that village, nearly horizontal tertiary sandstones form a

J Schaumburg, Lith.

VIEW IN JUTANA KUSS GROUPS 2-3-4 AND PART OF SALT CRYSTAL ZONE CAPPING THE CLIFFS.

broken range of hills, some five hundred feet above the plateau, just before these beds turn downwards into the valley of the Bunhár. Fragments of silicified wood frequently occur here in the lower greenish beds of this series.

Silicified wood.

The boundary lines of the various groups in this vicinity being decided almost entirely by erosion, run most irregularly, forming contours of the ground; patches of the newer beds are left outlying upon those below, and wide or narrow portions of the red flags and shales appear where the nummulitic and overlying beds have been removed. The boundaries are also sometimes affected by faults bearing north-by-west. Over this region too, the olive or brownish sandstones and conglomerates (with crystalline pebbles) of the "olive group" are to be found, though not always exposed, the group being apparently very thin. To the south-west of Ara village, the white earthy sandstone at the base of the nummulitic series, accompanied by purple and white variegated clays in its upper part, has a thickness of 23 feet. The sandstone is very soft, its earthy ingredient whitening the fingers; and the variegated shale or clay above it possibly represents the hæmatitic clay so frequently seen near the base of the nummulitic series in other places.

Boundaries.
Olive group.

A deep narrow coomb or glen* is cut back from the escarpment eastward of Jutána, and seems to coincide with an east-by-north fault, the rocks on the southern side having sunk considerably. The groups from the red marl upwards to the top of the magnesian sandstone, and part of the group above, are seen here; and here also, in an old mine, is the most easterly known exposure of salt-rock in the range, a bed of bad salt with large crystals of pure salt embedded in it. †

Jutána 'Kas.'

Most easterly salt known.

* Such a steep-sided ravine as is elsewhere called a 'khad' (khud), is here spoken of as a 'kás' (kuss), a word very generally used in the Upper Punjáb.

† Dr. Warth's Report, page 1[illegible], 18[illegible].

The depth of this cliff-enclosed ravine appears, from aneroid measurement, to be nearly 1,000 feet, made up of purple sandstone 450 feet, the dark shaly (silurian) band 200 feet, magnesian sandstone 250, and some 50 feet of the red, flaggy group No. 8, from which the red oxide of iron is washed down over the face of the hard cliffs, staining the light-colored underlying beds as deep a red as the overlying red zone itself. The remaining 50 feet may be allowed for the salt marl which appears nearly midway up the glen.

Silurian fossils.

This locality is interesting also as one of the two at which the silurian fossils, referred to *Obolus* or *Siphonotreta*, have been found. They were obtained on the southern side of the glen, where one or two cross-faults or slips seem to have let down the black shaly zone to the stream-level, not far from the salt-station and well within the glen. The fossiliferous beds are tough, dark, shales; thin brecciated sandstone layers occur near the bottom of the group, often of a greenish color, and some soft and light-coloured clays are used for washing by the natives.

Magnesian group.

In the magnesian sandstone group a coarse pisolitic or concretionary structure was observed throughout some ten feet of hard thin-bedded calcareous sandstone, and on some of the bedding surfaces slight traces were found resembling the tracks of annelids or mollusks, or sometimes having a fucoidal bunch-like grouping. Thin beds of coarse purple and white breccia also occur in places in this group.

West of Jutána.

For a mile and a half westward of Jutána the same sections are exposed by the escarpment and the ground above it; the nummulitic limestone in the latter position, having increased in thickness by 50 feet or more, projects southward from the main mass, accompanied by the underlying white sandstone, here with a ferruginous, red, and variegated clayey band, the former 16 feet and the latter 12 feet thick. Over this the coaly shales are represented by about eight

Nummulitic limestone and beds below it.

feet of dull brown olive shales, so far as seen without coaly layers. The lumpy part of the nummulitic limestone above this contains nodules of pyrites, and the rock seems to be very incoherent, the ground being covered by its debris.*

The metamorphic-pebble conglomerates, shales and sandstones of the "olive group" are apparently only locally present, but the underlying red zone with salt pseudomorphs is well seen: still largely composed of red shale at the top and more flaggy below. Here is its last appearance in force. From this country westwards it is much thinner, the upper clays mostly disappear, and it is evidently dying out. Some lumpy, brecciated, shaly, pebble-bands, seen hereabouts, are of unusual occurrence in the group.

SECTION V.—EASTERN PLATEAU.

Outline to east.

Between Diljaba mountain and the country last described, the convex contour of the Eastern Plateau rises with the dip of the tertiary sandstones, &c., at angles of 25,° 30° and 40°; but except at Ara these beds do not extensively overlie the plateau. Some outlying patches, however, occur near Saida Leri and Umrála (Oomrala of the maps). On that part of the border of the plateau facing the north in this neighbourhood, the angle of dip is steeper, up to 60°; and from the higher hills the sandstones and clays can be seen forming a broad synclinal trough which opens to the east, one side resting on the flanks of Diljaba, and the other upon the edge of this plateau, and the red clay zone occupying the hollow along the foot of the hills. The surface of the plateau undulates

Nummulitic limestone.

in places very considerably, the undulations frequently coinciding with the stratification of the gray nummulitic limestone, which, stripped of the overlying beds,

* The effect of violent rain, evidently recent, was well seen on a steep hillside covered with this debris—the loose stony covering having been, as it were, ploughed by the runnels, and the contents of the channels thrown off, forming ridges on either side of the furrow.

is most deeply eroded along the southern side of the table-land. The limestone is frequently fossiliferous, but its fossil-remains, as usual, are in bad preservation. Some beds, however, contain numbers of a small deeply marked oyster (*Ostrea Flemingi ?*) in a much better state; large Echinoderms and Gastropods are also common.

Chél.

On the north-western side of the plateau the narrow ridge of Chél rises 800 feet above it, having a summit elevation of 3,701 feet, and a length of about four miles. The ridge is formed by a much displaced and broken anticlinal of the magnesian sandstone group and would appear to have been faulted along both sides, slightly on the south-eastern, and to a much greater extent on the north-west side. (See section, fig. 18, Pl. XV.)

Along the south-eastern flank the nummulitic limestone rises gently, though forming ground difficult to cross in places. Close to the ridge a little valley intervenes, at the northern end of which, on the plateau side, are some bands of red, purple, and variegated, ferruginous sandstones passing downwards into coarse white sandstones, with red veins, and upwards into some black shales (doubtless the beds next below the limestone, on the usual horizon of the coal shales). They are of no great thickness, but remarkable for containing several well preserved lanceolate, dicotyledonous, leaves of small size.

Tertiary plant leaves.

Gravelly shale.

Not far from the place where these were found, on the north-east prolongation of the ridge, and down its northern slope, is a mass of greenish brown splintery and gravelly shale, having a peculiar appearance, weathering like soft trappean amygdaloid, containing white specks, metamorphic grains, pebbles, and even boulders of crystalline rocks. Layers of brown sandstone and conglomerate occur in and with this shaly mass, which appears to succeed the Chél hill beds without the intervention of the salt-crystal group. The bedding when seen conforms to that of the nummulitic limestone and passes below the lowest beds of that group.

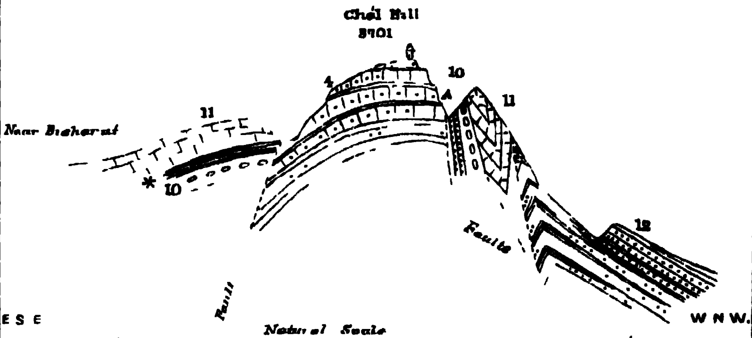


Fig 18 Section across Chél Hill

4, Magnesian Sandstone 10, Olive group 11, Nummulitic Limestone 12, Tertiary Sandstone &c * Fossil Leaves

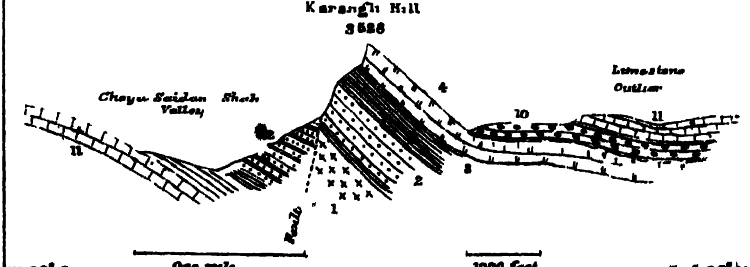


Fig 19 Karangli Hill Section

1, Red marl 2, Purple sandstone. 3, Dark shales Silurian. 4, Magnesian Sandstone
10, Olive group. 11, Nummulitic limestone 12, Tertiary Sandstone

Magnesian sandstone

The hill of Chél itself, at least at its northern end, seems to be mainly composed of the magnesian sandstone beds, typical varieties of this rock, the brecciated dolomitic and pisolitic or concretionary forms, occuring there; some of the beds are more sandy, some more compact and silicious, and here and there are red layers, with soft micaceous, dark and pale-gray sandstones having annelid burrows or fucoidal markings. In some spots too, dark micaceous sandy shales occur, a few beds together, of the entire aspect of the shaly silurian zone below. They are sometimes lumpy and flaggy, and on being narrowly examined were found at one place, south-east of the summit, to contain small, indefinite, plant fragments (probably of fucoids) and some small broken fish teeth (?), pointed like those of sharks.* As the axis of the stratigraphic curve forming the hill bends downwards towards both ends, these may be among the lowest beds exposed. On

Crushing

the north-western side the crushing and dislocation is extreme, the beds next in contact with the magnesian sandstone, &c., just described, being flaggy gray sandstones, with some coarse red layers and semi-calcareous grits, over which come conglomerates, and some of the conglomeratic shale, just now mentioned, at the point marked A in the section (fig. 18). Here another fault occurs, and a mass of crushed nummulitic limestone is let in between conglomerate and red Náhan beds, the junction of the latter with the limestone, being also a line of crushing and dislocation, cutting these limstones out entirely within a short distance.

Choya valley (East).

The whole of the Chöya-Ganj-Ali-Sháh valley below is occupied by the Náhan tertiary beds (sandstones, &c.), which are much disturbed, particularly along transverse line of fault between this and the head of the Phadiál valley.

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* These fossils being very obscure, and possibly belonging to detached upper beds of the *Obolus* or *Siphonotreta* zone, they have not been previously mentioned with either of these groups.

South-west end of Chél

Towards the south-west end of the Chél ridge the plateau limestone rests upon a thin red band, probably representing the salt-crystal zone, beneath which are the conglomerates and shale-conglomerate of the olive group; all dipping gently towards the plateau. These beds are brought up along the fault on the plateau side of Chél ridge, in contact with the rocks of this hill. Crossing the low arch formed by these beds, to the opposite side of the ridge, another fault is met with which brings a vertical portion of the same red bands against the ends of the Chél beds, and beyond these a mass of the underlying shale-conglomerate with metamorphic pebbles appears. A third fault places these in contact with the dark plant shales (?), overlying red and white, variegated hæmatitic clay, both of which are overlaid by the nummulitic limestone with a gentle dip towards the Potwár plateau.

Karángli hill.

The latter rock forms a large outlying mass, resting on the north-eastern flanks of the Karángli hill, turned up and faulted at both sides, but passing gently under steeply scarped Náhan sandstones, &c., towards the low ground. The limestone only occurs towards the northern end of Karángli hill, being there cut off by a prolongation of the most extensive fault of the whole range. From beneath it crop out gray, brown, and olive sandstones and flags, with bands of dark shale and conglomerate, in which nothing organic could be detected. Below these are other dark, shaly bands, in places flaggy, which contain a few small and fragmentary plant remains, and beneath all are strong conglomerates of metamorphic-pebbles, and shales, resting directly on the magnesian group, in a hollow at the south-west end of the Chél ridge; the intermediate red zone No. 8 having apparently died out.

Karángli scarp.

These magnesian sandstones, &c., rise (see section, fig. 19, Pl. XV), to the escarpment and form the summit of Karángli Hill,* (3,528 feet,) where they contain

* This elevation, and indeed all conspicuous heights on the Salt Range, including Sakesar itself, can be recognised from Murree on a clear day.

a few small scattered crystals of galena.* They are here rather more than 200 feet thick, and make a fine vertical cliff below the sharp top of the ridge. Beneath them comes the dark shaly *Obolus* zone, nearly 200 feet, and then 450 feet of the purple sandstone, from under which some of the red gypseous marl crops out, in faulted contact with the tertiary sandstones, occupying the mouth of the Choya-Saidan-Sháh valley. The strata forming Karángli hill belong to the western side of an open synclinal curve, the axis of which slopes at a considerable angle to the north-east. As the beds crop out from under each other, they also rise on the western slope of the hill, striking obliquely towards the fault at its foot in such a manner that the section is most full towards the southern end of the ridge.†

Structure of Choya valley (west).

The mouth of the Choya-Saidan valley is filled with the lower part of the tertiary sandstone series, embracing on the western side a broad anticlinal of the nummulitic limestone, along which the tertiary sandstones occupy the low ground as far as the village above named. These sandstones, &c., are cut off to the south-eastward by the continuation of the long line of fault striking from the direction of Diljaba up this valley. The magnesian group is less calcareous here than to the eastward, and from the prevalence of shaly and sandstone bands, in the absence of the salt-pseudomorph zone, is not easy to separate from the conglomeratic olive series No. 10. The nummulitic limestone has been denuded, but apparently it originally attained a thickness exceeding 150 feet.

Karángli to south-west.

From Karángli to the south-westward, the strike of the rocks on the Eastern Plateau side of the Choya valley coincides pretty much with the course of this depression, the

* As noticed by previous observers, this galena is much valued as *surma* by the natives in the vicinity.

† Mr. Theobald mentions (*loc. cit.*) a dyke of intrusive trap in the fault under the west side of Karángli mountain. The locality was searched, but no rock of the kind was found. Doubtless some of the same volcanic rock as occurs in Khewra gorge exists in connection with the salt marl, both here and at Gamthála (or Goddála) ravine. Its occurrence as dyke would be interesting; it certainly has not that appearance at all at Khewra.

hilly ground rising immediately from the fault exhibiting the series above the purple sandstone in a dislocated state. In the sides of one of the hills here, north-east from the village of Choya-Saidan Sháh, the "olive group" with its shales and conglomerates appears to be much thicker than usual (perhaps 150 feet), and the hill is capped by nummulitic limestone, within a synclinal fold of which, close by the village, is a narrow basin of the tertiary sandstones. At the eastern side of the hill upon which the upper Dilúr bungalow stands, the shaly conglomerate of the olive group, with its metamorphic pebbles, is seen, and a narrow, red, flaggy band representing the salt crystal-cast zone, partly occupies the southern face of the hill above, and overlies the magnesian group; the last is here chiefly composed of sandstones, and forms the floor of a long valley extending from Wahúli to Pid. In the low, scarped sides of this valley the groups Nos. 8 and 10, and the dark shales immediately beneath the nummulitic limestone, may be traced; the hæmatitic clay band at the base of the dark shales also appears occasionally.

Choya-Saidan-Sháh.

South-west of Choya, the ground between the Eastern and Kahún Plateaus is very much broken, its most marked feature being a steep ridge, in continuation with the Dilúr bungalow hill, one side of which slopes steadily at an angle of 35° into the Gamthála glen.

South-west of Choya-Saidan-Sháh

On the northern side of this glen the cliffs expose all the series from the purple sandstone up to the nummulitic limestone; on a narrow neck of which, faulted so that the beds dip in opposite directions, is built the village of Choya-Saidan Sháh. Further down the ravine the red marl crops out from beneath the purple sandstone, so that in this locality all the groups of the eastern series are visible. On the southern side of the glen are tertiary sandstones, faulted against the "purple sandstone" and "red marl," as if to dip beneath them; these tertiary beds rest upon a bare surface of nummulitic limestone deeply furrowed by numerous parallel rain-channels running directly down its dip. The limestone forms a ridge, the scarped side

Gamthála Kas

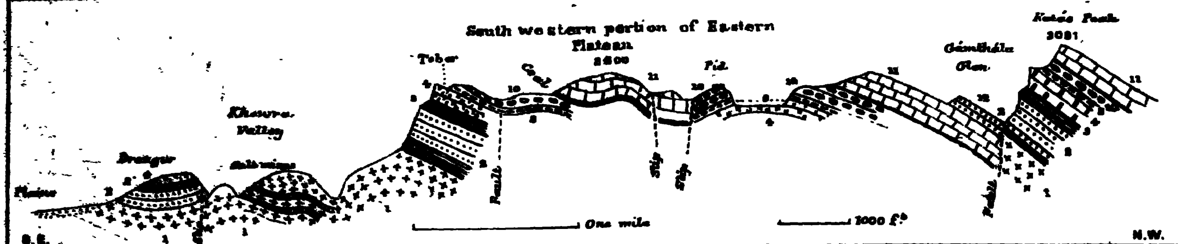

Fig. 20. Section from Khewra to Gámthála Glen near Choya Saidan Shah.

1, Salt marl. 2, Purple Sandstone. 3, Silurian. 4, Magnesian Sandstone. 8, Salt-Crystal Zone. 10, Olive group. 11, Nummulitic Limestone. 12, Tertiary Sandstone.

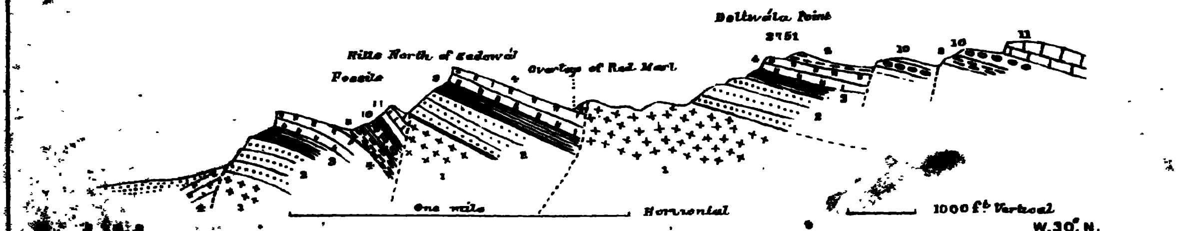

Fig. 22. Section over Doltwala Point Chambal Hills (West)

1, Salt marl. 2, Purple Sandstone 3, Silurian. 4, Magnesian Sandstone. 8, Salt-Crystal Zone. 10, Olive group. 11, Nummulitic Limestone.

of which overlooks the Pid end of the long valley previously mentioned as bounding the Eastern Plateau. Above the opposite side of that valley, the termination of the plateau undulates much, following the bedding of the nummulitic limestone, but the deeper excavations pass through the latter and expose the "olive group," the "red salt-crystal" zone, and the magnesian sandstone group below.

Southern side of Eastern Plateau.

The southern side of this Eastern Plateau is remarkable for the quantity of salt-marl exposed, and the suddenness with which it makes its appearance in force west of Jutána. (See section, fig. 20, Plate XVI.)

Jutána neighbourhood. Sudden development of the salt-marl.

Doctor Warth is of opinion that sudden increase of the salt-marl is due rather to undulation of the strata than to any dislocation. During the examination of the ground, some disturbance was observed in the glen north-west of Jutána, just where the red marl commences to show itself strongly: but this was more like the results of slipping than of violent faulting, and no great fault could be traced, intersecting the plateau northwards; where such a fault would in all probability have existed if dislocation were the structural cause of the development of this red marl in the Jutána 'beat.'* A certain amount of disturbance has nevertheless occurred, and where landslips are less numerous, such appearances as the small outlying hill of the magnesian group, upon which a chowki (No. 4) stands, west of Jutána village, and the abrupt way in which different groups abut against each other in the glen further north, would be taken as sufficient evidence of fracture, although here they are referable rather to the mere presence of the marl and the tendency of this rock to produce landslips than to faulting. In this and the next (the Kúsak "beat") the largest exposures of the marl in the whole range occur. This salt-marl rises at the Chambal (west) hills between the two "beats"

Large size and height of marl exposures.

* The southern side of the Salt Range is divided into "*beats*" for patrolling purposes by the Salt Department.

to an elevation of nearly 1,500 feet, and is singularly placed, an enormous slip or fault having allowed the mass of a whole group of hills, formed of the overlying strata, to subside so much below the level of the marl, on the crest of the ridge, that, either from subsequent atmospheric degradation, or from original displacement, the marl for a short distance absolutely overlies the magnesian group.

Abnormal position.

Fig. 21. Abnormal position of salt marl at Chambal hill (west).
1.—Salt marl. 4.—Silurian and magnesian groups.

It seems most likely that the salt-marl was left standing as a cliff when the subsidence took place, and afterwards under atmospheric degradation and superincumbent pressure, the cliff being destroyed, its material first formed a talus, and finally the heap now overlying the newer beds.

Jutána beat mines.

In the large exposure of the marl on the east slopes of these (western) Chambal hills, mines are not now worked, and but little is known about those which formerly existed. Old mining works, however, occur in several places, and Dr. Jameson in his paper* states that, at about two miles distance from Jutána, three mines were open in 1843. The inclined "shafts" which varied in length from 140 to 180 yards, passed through several small salt

* Page 198.

beds from three to six feet in thickness before reaching the large deposit, then being mined, and which had a thickness of one hundred and seventy to two hundred feet. The salt was, as usual, accompanied by gypsum, and the mines were situated about forty-five feet above the bed of a small stream.

Judging from the distance between these mines and Jutána it does not seem likely that Dr. Jameson referred to the bad salt in the ravine eastward of the village, but rather to some of the old workings to the westward; at one of these localities there is a twenty-foot layer of bad salt, but the others, forming a group of three or four, and lying to the westward still, are probably those visited by Dr. Jameson. From the height at which these mining localities are situated, if they contain the great mass of salt recorded by this writer (very nearly the same thickness as the Khewra beds), it may prove advantageous to re-open them.

Salt marl.

The marl of this beat often shows considerable masses of greenish gray colour, generally broken up and confused, but probably the remains of such gray dolomitic and gypseous layers as are found in other places to the west. In the more gypseous parts, horizontally undulating stratification may be occasionally seen.

Cliff sections.

The sections exposed by the cliffs above this marl are very much the same as those nearer to Jutána,* but owing to slipping are sometimes much confused; the next rock to the marl, for instance, on the road to Salowi from Jutána, being the salt-crystal band, here abounding with the sandy pseudomorphs, and

* There is a large space of ground near the ruined mining village of Jutána, bearing the marks of having been cultivated. On the removal of the miners to Khewra their fields may have been abandoned; but according to the statement of a native of the present village, this land was irrigated by means of the more easterly of two streams running close together from the north. This, he said, had suddenly become salt, and thus the cultivation had to be discontinued. It seems probable that the stream may have worn a passage down to some salt bed in the marl. There are numbers of ruined villages all along the foot of the range, about which nothing is known; they are all presumed to have belonged to miners of early periods.

overlaid by some dark shale and whitish sandstones of the "olive group," with carbonaceous markings. At other places, the succession is natural, but both of the last-mentioned groups are comparatively thin.

Road to Salowi.

On this road, overlooking a little valley much filled with calcareous tufa, and on the ascent up to Salowi, the sandstones of the "olive group" not far below the nummulitic limestone, were observed to be studded with scattered projecting knobs, which if concretionary had a very organic aspect, and much resemblance both to one another and to the opened valves of a *Trigonia*.* Above these sandstones, variegated, reddish, and conglomeratic sandstones intervened below the limestone. In this neighbourhood the plateau-limestone has been cut down into long valleys, exposing the underlying beds, and the junction of the limestone and the latter at one place is as follows:—

	Feet.
Part of the nummulitic limestone . .	30 to 50
White marly limestone	100
Black shale	6
White sandstone and black shale	50

The lower part of these rocks belongs apparently to the "olive group" and the representative of the coaly shales has dwindled away to the few feet mentioned; the strong and very white sandstone seen above Básghanwála having disappeared. Indeed, the rocks forming the lower part of this exposure are so obliquely bedded, that one band of sandstone, fully fifteen feet thick, thins out entirely within a hundred yards along the cliff face; where the stratification is so irregular, it is not surprising that much difference should be found in different sections.

Sadowál.

Southward of this place, an extremely dislocated group of hills rests upon the outer edge of the red marl, a couple of miles to the north of Sadowál. These hills are evidently formed of portions of the series slipped from their places, and disconnected, mainly by the fault along which the red marl for a few

* As suggested by Dr. Stoliczka.

yards overlies the magnesian group (fig. 21), as already mentioned (p. 150). Although greatly broken and displaced, the whole series may

Series exposed.

be traced in these hills, from the red marl up to the nummulitic limestone, a small patch of which is present.

On the western side of this outlying portion of the series, a mountain stream coinciding nearly with the faulted

Sucession.

junction of the red marl and overlying groups gives the following succession (see section, fig. 22, Pl. XVI) :—

Fault.

1. Red salt marl, abnormally placed.
4. Magnesian sandstone.
3. Black shaly band, silurian.
2. Purple sandstone.

Fault.

Nummulitic limestone, not seen here, but present at a short distance to the east.

		Feet.
10.	Olive group, sandstones and conglomerate, fossils in lower beds...	220
8.	Red clays, shales, and flags of the salt-pseudomorph zone ...	100 to 160
4.	Magnesian sandstone, compact and calcareous	150 to 200
3.	Shaly silurian band	100
2.	Purple sandstone, shaly below	500
1.	Red salt marl	1,500 ?

Boulder zone at foot of hills.

The red marl on the right-hand bank of this stream again overlies newer rocks ; here a portion of the flaggy salt-crystal zone, with much crushing and apparent faulting. The purple sandstones on the other bank of the stream become light-coloured at top, and the overlying silurian shaly band contains interbedded purplish sandstone and greenish shaly layers. The magnesian sandstone beds are sometimes very compact and of a gray color marked with red, and some of them expose on weathered surfaces the strange lenticular sections observed on Mount

Peculiar markings on surface of magnesian sandstone.

Tilla, the markings in the present case lying at different angles in the matrix, crowded together, and having sometimes a length of three inches by a quarter of an inch broad : some of the beds are brecciated.

At the base of the "salt-crystal zone" is a coarse gravelly sandstone band, and further up many of the harder bands have a purplish gray colour. The salt-pseudomorphs occur here again, with ripple marks and casts of desiccation-cracks on the flags, and there is a considerable development of the red clays or shales belonging to this zone, some of which are variegated with green spots. The largest part of the shales here occur (unlike those to the east) in the lowest half of the group. The "olive group" above contains boulder conglomerates, some of the boulders in which measure two and three feet in their longest diameter, and in a bed of soft, weathered green sandstone are the casts of large bivalve shells, before alluded to as of cretaceous appearance.

Olive group.

The following section of the "olive group" in these hills is from Dr. Waagen's notes:—

Fault.

			Ft.	In.
CRETACEOUS?	17.	Gray and yellow thin-bedded sandstone, with irregular papery layers of coal	6	0
	16.	Light yellow nodular sandstone, with indistinct coaly plant-remains ...	2	0
	15.	Yellow and gray spotted, thin-bedded sandstone, with a few traces of coal	12	0
	14.	Whitish yellow sandstone, with coaly plant-remains	6	0
	13.	Strong coaly, sandy layers, with lenticular small masses of coal ...	5	0
		Yellow and gray spotted, thin bedded sandstone	7	0
	12.	Black sandy bed, with much coal	0	8
	11.	Hard yellow sandstone, with brown ferruginous veins	10	0
	10.	Gray shale, with coal	6	0
	9.	Irregular bed of impure resinous coal, average	1	3
	8.	Yellow brittle sandstone, ferruginous veins	4	6
	7.	Thick white sandstone, with yellow stripes	20	0
	6.	Thick greenish soft sandstone, few traces of coal	4	0
			Feet.	
CRETACEOUS.	5.	Dark greenish gray sandy shale and thin-bedded sandstone ...	30 to 40	
	4.	Thick grayish green sandstones, with irregular beds of gravelly conglomerate, and, in the lower part, the bivalves of the olive group	15 to 20	
	3.	Conglomerate, blocks of crystalline rocks	3 to 30	
		Dark purple shale, with thin bands of greenish sandstone ...	50	
	2.	Red thin-bedded sandstones and flags with salt-pseudomorphs ...	100	
	1.	Magnesian sandstone group	150 ?	

From the prevalence of coaly beds in the upper part of this section, which is unusual in the group, it may be doubted whether the upper portion with a separate bracket is not a local representative of the coaly shales beneath the nummulitic limestones.

Kúsak 'beat.'

In the Kúsak "beat," westwards of the Jutána one, the salt-marl is even more largely exposed than in the latter, and two outlying portions of the overlying rocks form hill-groups surrounded by it. In the upper part of this marl, at the western side of the "beat," there are strong purple bands, and also a sort of gypseous pseudo-breccia. Salt is seen in several places, even near the mouth of the western of the two streams which drain the "beat:" and there are several old mines within its valley. In one of these, Dr. Warth found a seam of salt (with some marly bands) one hundred and fifty feet in thickness, dipping at a high angle to the west-north-west.*

Salt.

Other old mines occur also in the eastern portion of this "beat," mostly inaccessible, and the natural exposures of the salt by streams, &c., show little that is instructive, any stratification marked by the gypsum being contorted.

Series at Chak Shaffi.

The two isolated hill-groups referred to show the series as high as the magnesian sandstone, the rocks being much disturbed. At the east side of the largest of these exposures on the road from Chak Shaffi to Kúsak, the following were noted:—

		Feet.
4.	Semi-calcareous sandstones, light in colour, belonging to the magnesian group	120
3.	Black shaly band (silurian)	12
2.	Purple sandstone, part of the upper fifteen or twenty feet pale, nearly white, and overlaid by a coarse white conglomeratic layer, base not seen, measured	172

* Dr. Warth's Report, 1872, page 184.

Cliffs.

The cliff-sections above the marl, where not disturbed by slipping, show the same series, the hard sandy dolomitic beds forming the cliff edge, overlaid by the "salt-pseudomorph zone," and this again by the conglomerates and sandstones of the "olive group," the whole covered over by the nummulitic plateau-limestone. Where this spreads over the higher portions of the ground, under the action of the atmosphere and rain, its fretted, gnarled and jagged surface forms narrow tortuous channels, in which one can walk more than waist deep, and which are most difficult to cross when covered by scrub jungle.

Near Bátli.

At the head of the western Kúsak glen, not far from the village of Bátli, the cliffs exhibit the series as follows—the thickness being estimated, as the ground was too steep to be measured:—

	Feet.
11. Nummulitic limestone, with some white beds below ...	250
10. "Olive group" sandstone and conglomerates, varying up to	200
8. Red flags "salt-pseudomorph-group"	150
4. Light-colored sandstone and dolomitic beds . ..	150
3. Black shaly zone, silurian	100
2. Red and purple sandstone	300 to 500

The "olive group" seems here to be very thick in some localities, and very thin in others. It consists of dark gray and olive sandstones, olive-black shales and some beds of red shale, doubtfully referred to this group on account of slipping, these probably forming the top of the group below. Conglomerates of metamorphic pebbles occur as usual. Some red sandstone and shaly bands also appear just beneath the nummulitic limestone, but they are of subordinate character, and the coal shales, if present, are generally concealed by the talus at the foot of the limestone scarp.

Kúsak.

The old fort of Kúsak, a stronghold of the Sikhs, is perched upon the lofty and precipitous southern end of a spur from the plateau (see fig. 23, Pl. XVII). The neighbourhood is much disturbed by slips or small faults, and the pre-

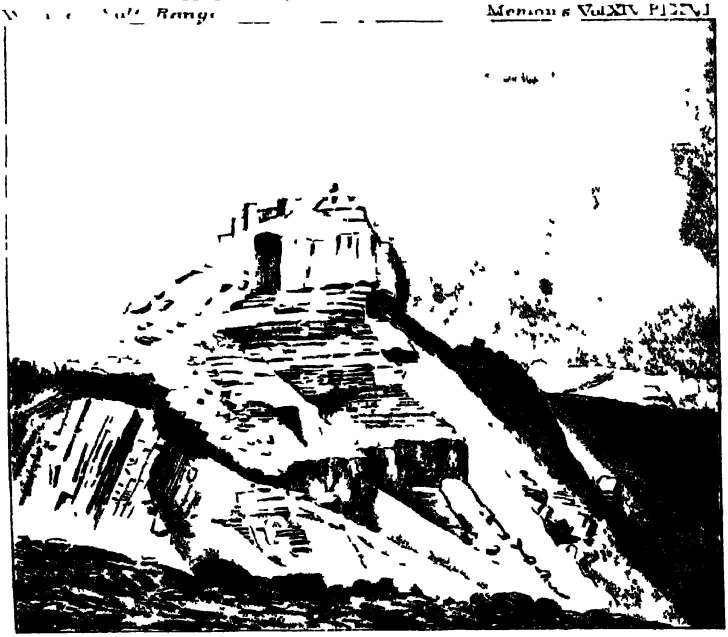

Fig. 23 Kurak Peak & Fort
looking Northwards

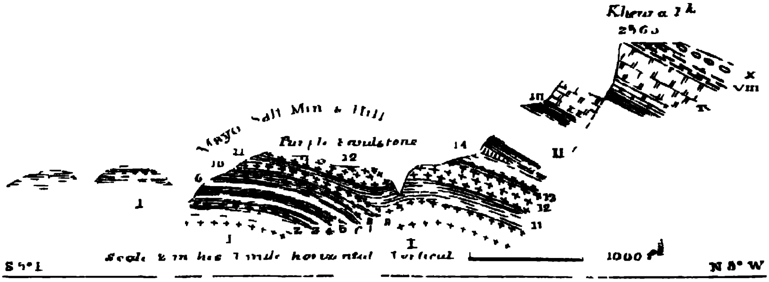

Fig. 24 Sketch Section of Kheura Glen from 1 inch map and a MS sketch by Dr Warth
(Corrected to August 1872) heights much exaggerated

I Salt marl including 2 Bilkas ... seam probably lowest ? 3 Salt marl 140 ? 4 Salt 50 ft Pharwala Seam 5 marl 100 ft 6 Salt Sujowal seam 50 ft 7 marl 25 ft 8 Salt 150 ft (Big Buggy seam) 9 marl 10 ft 10 Salt 25 ft (Rahun seam) 11 White gypsum 200 ft 12 Brown gypsum 140 ft 13 Brick red gypseous marl 130 ft 14 Place of Trap-ash and white gypsum 4 ft and upwards II Purple sandstone III Silurian IV Magnesian Sandstone VIII Salt crystal zone X Olive group

cipices are inaccessible, but the section seems to be generally the same as eleswhere, though the group, No. 3, looks thicker, and seems to contain some harder beds than usual.

The red marl is seen far below the fort, the purple sandstone follows next above; and the dark shaly zone (No. 3) is capped by the magnesian sandstone, on which rests a small patch of the red flaggy pseudomorph-zone.

Between the fort and the plateau the rocks are much broken, and the ground is covered by heaps of disintegrating rock. The "olive group" and "salt-crystal zone" skirt the base of the "nummulitic limestone" cliffs, and a fault seems to extend from the eastern side of Kúsak peak, up the shallow valley in the plateau-limestone, through which the road from the fort passes northwards.

Spur to west.

On the spur which separates the Kúsak from the Khewra "beat" to the west, and along the neighbouring part of the plateau, the ground is much broken and very hilly, the same series as before being traceable in the cliffs and higher eminences as well as the upper portion of the underlying beds, exposed by denudation, beneath the limestone of the plateau.

Coal shales.

In this direction, too, where a high peak of limestone rises to the north-north-east of the Mayo mines, there is a small exposure of the coal-shales dipping to the north-west at 24°, just beneath the nummulitic limestone. Coal was said to occur here, but it was not visible. In the vicinity of the road from Khewra to Kúsak, the rocks are greatly dislocated, as well as to the southward; several fragmentary outliers of the nummulitic limestone, patches of the red flaggy zone, the lateritic variegated clay, and even a small portion of the coaly shales just now alluded to, occurring, detached, and probably none of them actually *in situ*. Further out towards the plains, the least disturbed ground is occupied by the massive beds of the magnesian group undulating in many directions, but the hill-slopes are greatly covered by debris. Both the silurian

shales and the purple sandstones appear to have lost much of their thickness in their last exposures towards the plains.

The Khewra valley is much smaller than either of the last mentioned "beats," and the main scarp of the plateau, approaching nearer to the plains, the glen appears deeper (see frontispiece). Having passed a narrow defile between outlying hills, overspread by the purple sandstone or the dark shaly silurian zone, and capped by the dolomitic sandstone or its detritus, the valley opens somewhat, but is still hemmed in on all sides by high ground; that to the westward only being entirely composed of the red marl. The strata appear from their present disposition to have had originally a dome-shaped arrangement, dislocated along the inner side of the outer hills, or else a general landslip of the overlying beds in that direction may have taken place; narrow glens along the strike among these outer hills show on one side the overlying rocks, and on the other red marl and gypsum only. The marl is quite of the same kind as already described, having a decided similarity of aspect throughout, but its arrangement, so far as it is connected with the rock-salt beds, is better known through the exertions of Dr. Warth, whose report, mining plans and sections show that there is a regular sequence in the upper part of the group, though one which may not be minutely recognisable in other localities.

Outer hills.

Marl.

The mines have been so often described and with so much detail* that it will be unnecessary to do more than state that they are the largest and most important of the whole range, and probably the most extensive salt mines in the world. Old chambers occur in them of 80, 120, 240, and 320 feet in width, and 40, 60, and up to 130 feet in height, besides natural shafts formed by rain water, one of which is 212 feet deep.

Mayo Mines.

These old workings have long been in a most dangerous condition. That they ever grew so large, was owing to the ignorance of system

* Authorities cited, *ante*.

exhibited by the old workers, and the result has been constant danger and tremendous falls—a large one having taken place so late as 1870, in consequence of a huge supporting pillar having been undermined, and left standing over a lower chamber, upon a comparatively thin shell, which it eventually broke through. When the mines were visited in 1869-70, the position of some of the miners was anything but enviable; perched upon a lofty tripod of slender sticks, picking at the roof of one of these high chambers, a roof probably full of fissures and utterly unsupported for many yards; while in other places, considered still more dangerous, huge masses of salt-rock between the fissures impended like the displaced key-stones of enormous arches.* The heavily-laden women and children struggling up the well-made incline of "Purdon's tunnel" had evidently, bad as it was, the better place.

The beauty of the interior of these mines has often been noticed; their extent appears more impressive than their smoke-begrimed sides and roof, but the effect, when they are lighted, is very fine; lines of small lamps at different levels and inclinations marking those places in the vast chambers where footing can be had, while some hay set on fire here and there, for a few moments, lights up portions strongly, others vanishing in distance or in smoke.

Position of the mines.

The mines have been excavated, some in the same and some in different beds of salt, all of which lie in the upper portion of the marl, though most of the worked bands occur at a considerable depth from the surface. The following is their arrangement according to Dr. Warth, from the purple sandstone downwards (see section fig. 24, Plate XVII).

		Feet.
14.	White gypsum, average	5
13.	Brick-red marl or gypsum (*i. e.*, gypseous marl)	130
12.	Brown gypsum (? purple gypseous marl)	140
11.	Lower layer of white gypsum	200
	Salt marl and salt	550 to 600

* I was told that the workmen preferred these localities to places where the salt was more solid, because a single blast in such a situation detached more of the mineral.

The latter is grouped as follows :—

		Marl and Gypsum.	*Salt.* Feet.
10.	Salt bed (Rehan's seam)	...	25
9.	Salt marl	10	...
8.	Salt bed (Big Buggy seam)	...	100
7.	Salt marl	25	..
6.	Salt bed (Soojeewal seam)	...	50
5.	Salt marl	100	
4.	Salt bed (Phurwalla seam)	..	50
3.	Salt marl	140	...
2.	Salt bed (Billiwala seam ?)	...	50*
1.	Salt marl	?	...
	Total ...	275	275

The colour of the salt is red and white; red earthy, or merely coloured, layers being very numerous in some of the beds, generally from ten inches to a foot apart, and about one inch thick. As a rule, these layers of deposition are parallel. The salt beds and alternating marls appear to be nearly flat in the southern part of the glen, and towards that side of the salt mines' hill; but within this hill they curve rapidly downwards, dipping at 60° and 70° towards the west of north, an undulation of the strata bringing them again at a lower angle beneath the cliffs at the head of the glen (see section fig. 24, Pl. XVII). The main mass of the gypsum overlies the salt, and is succeeded by the purple sandstone and other groups in their proper order.

Relations of the series.

These can only, however, be considered the general relations of the salt-bearing part of the marl; and it is probable that there are still other salt beds on different horizons, one of these occurring in a side ravine, on the left of the Khewra glen at the junction of the gypseous portion of the marl with the purple sandstone.

* Dr. Warth has some doubt about this last seam (No. 2). The section is known down to the bed No. 3, and the last is assumed as probably another bed.

Leaving the mines and proceeding along the upper gorge, the top of the marl, which is all more or less gypseous, has in places a dull purple colour (probably representing that portion of the group described as "brown gypsum" by Dr. Warth). Flaggy bands of dolomite and massive layers of gypsum also occur in the marl, the uppermost being a white band of the last mineral, immediately beneath the "purple sandstone group."

Volcanic rock.

Associated with this gypsum is the volcanic rock of Khewra, and near it are some grey gypseous and carbonaceous shales, as already mentioned (page 75). This upper portion of the salt-marl seems to be highly saline, for the stream which comes from the plateau above as soon as it enters the deposit becomes so charged with salts that the pebbles in its bed are all frosted over with a thick incrustation, growing for some inches upwards in fantastic pedunculated and other dendritic forms.

Overlying rocks.

Ascending this stream, its narrow ravine exposes a good section in the purple sandstone, marly or shaly as usual below, and its upper beds forming the lower part of the cliffs between the glen and the plateau. Its thickness hereabouts is estimated at from 450 to 600 feet. The dark shaly zone above it is also well marked all along the cliffs. In the main ravine, where the track upwards leaves the stream bed, is the locality at which the silurian fossils, *Obolus* or *Siphonotreta*, where first discovered.

Silurian fossils.

These little shells occur in numbers in dark sandy micaceous shale, but some layers contain them in greater quantity than others. No fossils besides these could be found in their neighbourhood, except obscure fucoids or Annelide markings on flaggy layers; some of these layers are calcareous and glauconitic.

The dark band which contains these fossils is here fully 150 feet or more in thickness. It is immediately succeeded by the magnesian sandstone band, as usual prominent in the cliffs and exhibiting well the northerly inclination of the beds, at angles of 35° and 40°. The group

chiefly consists of fine grey, gritty, light-coloured sandstones, and the more compact dolomitic rock is not so prevalent as it is upon the outlying hills to the southward. The group is about 250 feet in thickness. Over it comes the red salt-crystal zone, in places as thin as 30 feet, but still so strongly ochreous that the rain washes the iron oxide out and stains the rocks below.

The olive conglomeratic shale with metamorphic pebbles belonging to the "olive group" overlies this red zone, and in the same group are included many massive soft sandstones, the whole exceeding 150 feet in thickness. These beds and the red group lie chiefly behind or on the plateau side of the general escarpment. Near the head of the ravine a narrow vertical mass of nummulitic limestone is brought in by a north-east south-west fault, together with some soft black and grey gypseous shales having an apparent thickness of about fifty feet. These overlie the "olive group," conglomerates, &c., and come just beneath the limestone. Further northwards, undulating, inclined, and disturbed masses of the nummulitic limestone rest upon this olive group and the

Coal.

intervening shales (which, again, contain layers of coal in their outcrop), extending from this valley to the neighbourhood of Pid. At a distance of about half a mile southwards from the latter village, some mining operations have been carried out upon the coal, beneath a displaced mass of the limestone.

The coal-shales here dip with the limestone at 40° to the northward, and rest upon soft friable whitish sandstone—some of the basal beds of the nummulitic series. The section measured as follows:—

		Ft.	In.
7.	Nummulitic limestone, part	100	0
6.	Rotten, white, and grey shale	10	0
5.	Coal ... ... 3 ft. to	3	9
4.	Dark-coloured shale	0	11
3.	Coal	1	2
2.	Black shale	23	0
1.	White earthy sandstone, full of plant-fragments.		

In these dark carbonaceous shales there is much pyrites, and a white aluminous efflorescence occurs, enclosing plant-stems and pieces of brown lignite. In another place close by, the thickness, from the shale No. 6 to the coal No. 3, was ten feet, and the upper coal was three feet six inches, the lower being one foot nine inches thick; the black shales below were only six feet, and an underlying whitish clay bed ten feet, so that the coal and associated beds appear to have been very irregularly deposited. The shales contain nodules of hard clay enclosed in gypsum, and the lowest rock of the series exposed is a thick mass of rapidly weathering, variegated, white, green, and red clays answering probably to the hæmatitic beds of other places.

Pid road. Ascent.

Sections of the rocks are frequently exposed on the turnpike road leading from Pind-Dádun-Khán and Khewra northwards *viá* Choya-Saidan-Sháh. The first ascent exposes much-broken beds of the purple sandstone, overlying the red and purple marl, and overlaid by the flaggy and shaly silurian fossil zone, its laminæ being often marked by black glossy surfaces. Above these are grey sandstones, and a fifty-feet band of fine hard oolitic rock, belonging to the magnesian sandstone group. Higher up, the beds are dark and shaly, with thin layers of pale green-banded sandstone, glauconitic, and bearing obscure Annelide markings, and above all are fine-grained strong white sandstones which might make good building stone, but are much shaken.

To the northward, the salt-marl is brought into contact with the beds just described by the slip or fault which has been noticed as running along the back of these outer hills. The marl, which contains hard flaggy compact layers of an apparently calcareous or dolomitic rock, is here intersected by a deep road-cutting exposing quantities of gypsum and the usual want of structure. Further up the ascent, the road leaves the marl, and the purple sandstone is again seen in its proper position, followed by the two succeeding groups. Still higher up the slope, slipping of the beds has taken place, and the red salt-crystal zone is seen to contain a mass of hard, sandy, metamorphic-pebble conglomerate, of exceedingly confused

aspect, including portions of its flaggy layers, looking as if detached by river action. The thickness of this red zone is about 40 or 50 feet, but the "olive group" above it is still very largely developed, and includes some reddish sandstone bands in its lower conglomeratic portion. Layers of this metamorphic-pebble conglomerate, 19 feet in thickness, occur, and the whole group may be over 200 feet thick. The beds become flatter as the plateau is reached, the road passing hereabouts chiefly through this olive group and slipped masses of the nummulitic limestone. The glen to the westward below the road is so full of fallen and displaced masses of the series that it is difficult to say which rocks are *in situ*.

SECTION VI.—DANDÔT PLATEAU AND SPUR.

Dandôt.

The undulating table land of Dandôt forms a sort of continuation of the Eastern Plateau, but at a lower level, and is covered as usual by the nummulitic limestone, detached portions of which cap the spur extending from the plateau to the west and south of the glen of Makrách. The village of Dandôt is perched upon the edge of lofty cliffs which overlook the plains and expose a fine section of the rocks (fig. 25, Pl. XVIII); the arrangement, however, presented by this differs much from others in the neighbourhood, and in one respect, from all others of the range,—namely, in the occurrence of a dark zone of sandy and shaly beds apparently near the base of the purple sandstone. This zone so exactly resembles the silurian one above those rocks, as to afford reason for the supposition that it has been faulted into its present position, although the dip of the whole cliff-section seems regular, and would indicate a sequence from top to bottom.

Cliffs.

Peculiar shaly band.

Either such faulting would seem to have occurred, or else there is an unusual development of the shaly group No. 3, accompanied by a great diminution of the purple group No. 2, and a sudden appearance of another large group of red sandstones, overlying the silurian zone, and interposed between this and the magnesian sandstone.

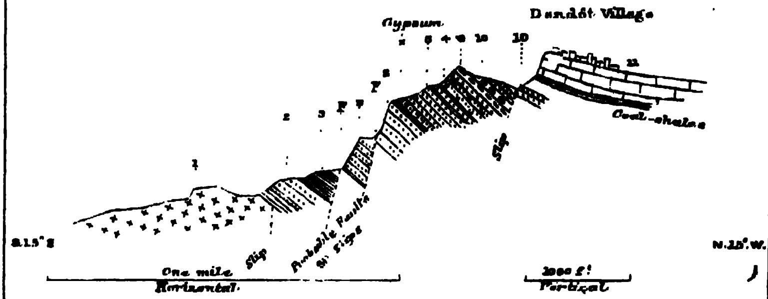

Fig. 25 Section through Dandôt village.

1, Salt-marl. 2, Purple Sandstone. 3, Silurian. 4, Magnesian Sandstone. 9, Salt-crystal zone. 10, Olive group. 11, Nummulitic limestone. F, Faults.

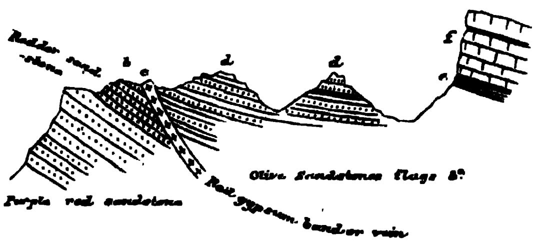

Fig. 26. Section West of Dandôt.

a, Purple Sandstone. b, Red Sandstone. c, Gypsum band. d, Olive Sandstones flags &c. e, Place of Coal-shales. f, Nummulitic limestone.

The series.

The gypseous marl at the base of the cliffs is greatly eroded, harder masses projecting from one to two hundred feet; deep gullies are also cut in it, and some of these are naturally bridged over in places by the marl. This is succeeded by thick purple and greenish variegated clays or shales, passing upwards into purple sandstones. Then comes the dark olive and blackish shaly zone above mentioned, passing downwards into thin light-coloured sandstones, and containing some markings like those of Annelides. Black and greenish films separate many of the beds, and the shaly part contains a thirty-feet red band; the shales are generally micaceous. Owing to the supposed fault or slips, these beds appear to be succeeded by a thick mass of reddish purple sandstone exactly similar to No. 2, becoming flaggy towards the top, and, from its great thickness, this is supposed to be nearly doubled by other slips or faulting. More red sandstones overlie this, shaly underneath, and in this shaly portion is a bed or vein of reddish and white gypsum, 30 feet thick, and in character quite resembling that of the red marls below. Grey, silicious, and calcareous coarse grits succeed, very dark in colour and alternating with dark shales below; the silicious and calcareous beds may represent the magnesian sandstone No. 4, and the lower portion would occupy the place of the silurian zone No. 3. Then follows the red, flaggy, salt-pseudomorph zone No. 8, including layers of grey shale and thin grey sandstone, in the lower part. Over this is a considerable thickness of dark shales, with a twelve-feet band of metamorphic-pebble conglomerate evidently that of the olive group, No. 10, and above these are reddish and white sandstones, projecting from below the shaly talus, at the foot of the Wychler cliff, the vertical portion of which, at the fine springs below the scarp, measured 179 feet.

SECTION BELOW DANDÔT VILLAGE AND CLIFFS.

Groups.		Ft.
No. 11.-4	Nummulitic limestone	200
	Coal-shales, traces to westward	...
	Talus ... ... room for 150 feet of beds	
		(165

Groups.		Ft.	
No. 10.—	Red shales	... 56′	
	Light-coloured sandstones	... 20′	
	Shales	... 20′	
	Whitish sandstones	... 14′	
	Red clay or shale	... 36′	
	Greenish shales	... 28′	
	Metamorphic-pebble conglomerate	... 12′	
		—	186
No. 8.—	Red shaly and flaggy zone (salt-pseudomorph band)...	...	120
No. 4.—	Silicious and calcareous grits	...	200
No. 3.—	Dark sandy beds	...	100
No. 2.—	Red sandstones and shales, with a thirty-feet band of gypsum ...		200
	Red shaly sandstones	...	400 probably repeated.
	More solid, red sandstones	...	
	Thick and flaggy red sandstones	...	
	? Fault or slip.		Ft.
No. 3 ?—	Black shaly band, with whitish flaggy sandstones below, probably exceeds	...	150
No. 2.— part of ?	Red shale	...	30
	Purple and green variegated shale and sandstone ...		... 70 to 250
No. 1.—	Gypseous salt marl.		?

To the westward of this line of section, within a mile, the faulting and slipping seem even greater, giving the appearance of an enormous thickness of the purple sandstone. The red gypseous band marked in the section continues for some distance along a curving line, and appears discordant to the bedding, as if filling a reversed line of fault or fissure in the western part of the course. (See figure 26, Plate XVIII.)

Westward of section.

Further still to the westward (fig. 26) at the head of a deep narrow glen opening to the south, the section seems more normal as to thickness, and the gypseous dark coaly shales are seen beneath the limestone escarpment of the plateau.

Gypseous band.

Near the head of this ravine, a narrow neck of limestone connects that of the plateau with its lower continuation westward, and upon both sides of this neck the coal-shales are exposed. At the southern locality, they are more than

Dandôt coal.

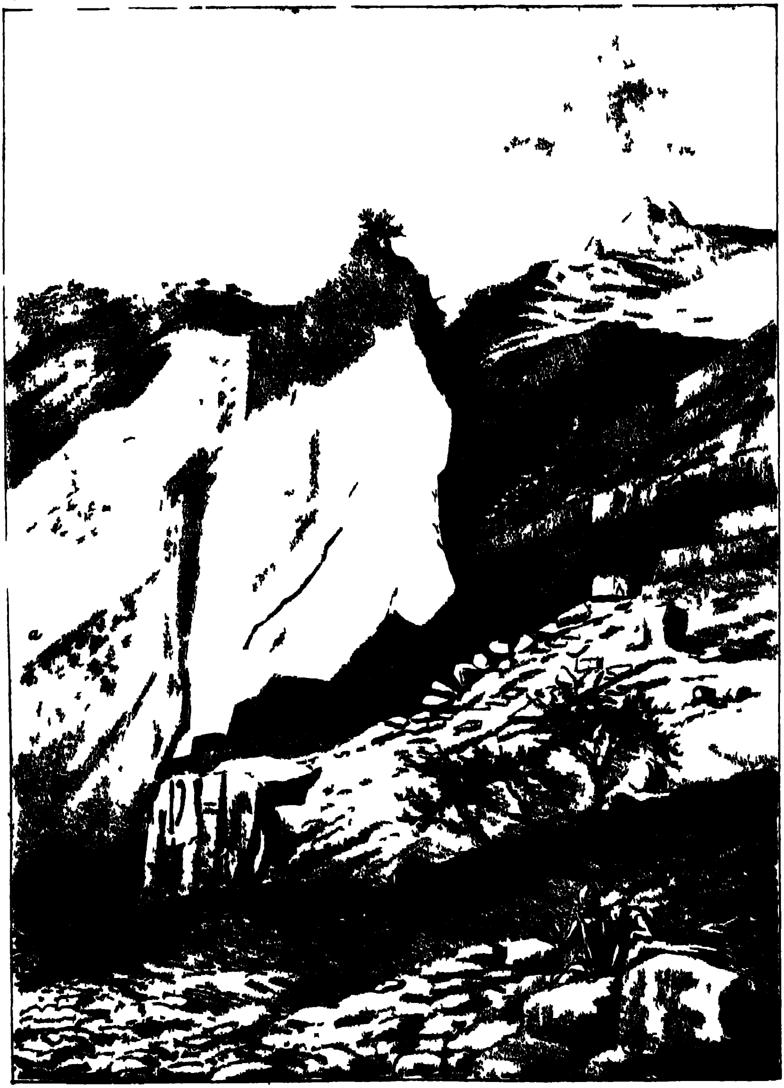

Fig 27 Mariala Coal driving
a Limestone cliff b Sandstone c Coal-drift

100 feet thick, but are greatly split up by thin sandstone bands. These shales rest on red sandstones, and are overlaid by light-coloured sandstone beds; more shales overlie the latter, becoming flaggy above. A fault brings the whole against the nummulitic limestone; just beneath which some of the uppermost of the dark shales, and some two feet of the coal* are badly exposed. The coal burns with difficulty, giving off much gas and sulphurous fumes.

Samundri bungalow, locality.

Northwards from this locality, on the opposite side of the neck of nummulitic limestone, the coaly shales are seen again, near a dilapidated bungalow. Some larger openings have been made into them here. In three of these the coaly portion was found to differ; in one, there were three small bands and three or four, 4 to 6-inch strings of coal; in another, the coal and shale were so blended that the thickness of the former was undefined; and in the third, the coal was 6 feet thick, but divided almost in the middle by a 7-inch band of grey shale. The coal weathered away rapidly owing to its sulphurous character, and some parts of the coal-shale had taken fire and burned red. Just beneath the coal a hard, yellow, slightly calcareous rock, deeply weathered, and blue within, contained some obscure Bivalves and some *Rotalinæ*. Underneath these are some coarse reddish and white soft sandstones, which may belong to the same series. The coal seemed here in greater quantity than in the other places in the neighbourhood; but as the limestone under which it lies is very limited in extent, so also must be the coal.

Mariálá.

Within a mile to the westward there is another locality, where the coal-shales and limestone are faulted against hard grey sandstones, capped by 100 feet of red sandstone and shales. The cliff in which the coal occurs was inaccessible, the road to the old driving having slipped away, but the entrance to the mine could be seen on the opposite side of a ravine (Plate XVIIIa). It

* The guide who pointed it out ate some spoonfuls of the coal with apparent relish, no doubt regarding it as a medicine, and did not seem the worse during the rest of the day.

did not appear here that the junction of limestone and shales was regular, these having been crushed into irregularities of the under surface of the limestone by slipping of the whole mass.

The sandstone.

The red sandstone brought against the limestone here seems to succeed the grey sandstones below regularly; but as the latter are of the character of those belonging to the magnesian sandstone group, and no such strong red sandstones are known in a similar position among the upper beds to the east, it is most likely that they belong to the group No. 5, which comes into the succession not far to the westward.

Níla coal.

There is yet another locality at which the coal-shales are visible in this neighbourhood, rather more than a mile to the westward, under the salt miners' old hot-weather village of Níla, on the northern scarp of the tongue of limestone which caps this spur of the hills. The coal is rather more than a foot thick, occurring in the upper part of six or eight feet of black shales, underneath which a yellowish calcareous rock reappears, similar to that noticed at the northern Samundri locality; grey and ferruginous shales overlie the coal, and above them, just beneath the limestone, is some fine powdery soft white sandstone with carbonaceous markings. The whole group of beds associated with the coal from the limestone downwards is twenty-eight or thirty feet in thickness.

Associated rocks.

Other rocks.

Beyond the small capping of limestone, the rest of the ground forming this spur is very much broken. The salt-marl rises high on the southern flanks of the hills, and is much exposed in the deeper glens: the purple sandstone cliffs start immediately from it, but the most of the higher ground is covered either with light-coloured rocks, very generally sandstone, of the magnesian sandstone group, or with their debris and that of the overlying rocks.

On the Makrách side, this spur is bold and steep, having more the character of an escarpment than the other side. The rocks, too, dip to south-by-east at higher angles than on the outer slopes. The purple sandstone shows a thickness of some three hundred feet, but the shaly group No. 3 is insignificant, being apparently united with the light-coloured sandy beds of No. 4. A thin red band or two occur near the base of the "olive group," overlying the possible representative of the group No. 5, this being near the place where it commences. The whole sandstone series below these red bands is about three hundred to four hundred feet thick, and at the eastern end of the Makrách salt-marl valley the beds are bent into an anticlinal curve, which on its south-eastern side passes below the Dandôt plateau, and to the north-east under the long limestone ridge from Choya-Saidan-Sháh, which forms the inclined southern side of Gámthála glen.

Makrách side of spur.

Anticlinal in glen.

Near the mouth of this glen just beneath the nummulitic limestone, there is strong development of the coaly shales with their coaly band, here two feet three inches thick. A good deal of slipping in the vicinity obscures this place, and the dip is very high to the north, so that the shales appear unusually thick, the outcrop being 130 yards wide with a dip of 70°. The shales include some white, lumpy, sandy, and gypseous beds, and the lower part contains plant fragments. Underneath the coal-shales are soft white sandstones and red shales overlying a thick mass of the usual metamorphic-pebble conglomerate and sandstones of the "olive group" with which these red beds are provisionally placed. The whole group is thick, but much concealed. From beneath these beds, the red, rippled, flaggy and shaly rocks, with micaceous layers and Annelide tracks, representing the "salt pseudomorph zone," make their apppearance; and in the undulating light-coloured semi-calcareous beds of the "magnesian group" the white oolitic bands with a thickness of twenty feet (the same as on the turnpike road near Khewra) were again observed.

Coal series and beds below.

SECTION VII.—THE KAHÚN PLATEAU.

Description.

This wide portion of the table-land of the Salt Range is almost entirely occupied by the nummulitic limestone, which is not unfrequently cherty, as in the neighbourhood of Dilwál. The maximum heights of the plateau are at nearly the same level, and the central part is occupied by flat east and west valleys, with limestone ridges between, the southern edge being tilted somewhat and sloping to the north with the bedding of the rocks. The valleys are occupied by fertile soil washed from the higher portions. With regard to fossils, the limestone is quite the same as that to the east.

Northern side.
Tertiary sandstones.

All along the northern side of this plateau, the lower (Náhan) beds of the tertiary sandstone series dip from it northwards, passing under the Potwár country at angles varying from 30° to 50°. These beds have not at all the general look of the Murree or of the Bakrála pass rocks; the purple sandstones of the latter and general purplish colour are both wanting. The lowest beds are strong grey sandstones, in places greenish, having a calculated thickness of 4,500 feet. Above these comes the "red clayey zone," between 200 and 300 feet in thickness, and then the "orange and grey series," with some conglomerate beds, in places a good deal contorted, and occupying much of the country to the north. Just on the flanks of the range there is in places a set of more recent-looking conglomerates and sandstones, with a steep dip to the north, and resting with doubtful conformity upon the older tertiary sandstones. These may probably be referred to a post-tertiary period. As is usual in such ground, ravines or "*khudderas*" prevail extensively in the lower situations, and the harder sandstones rising on the flanks of the range form numerous, more or less continuous, escarpments.

Eastern part.

The eastern end of the limestone of the Kahún plateau, as already mentioned, forms an open anticlinal curve, the axis of which sinks to the eastward, so that it is

embraced by the tertiary sandstones outside of and within the Choya-Saidan-Sháh valley, west of the fault which brings these against the older beds underneath Karangli hill and elsewhere.

A synclinal, corresponding with this anticlinal curve, its axis dipping also to the eastward, terminates the valley portion of these tertiary sandstones, close to the bungalow of Choya-Saidan-Sháh, where the limestones rise out from beneath them. The termination of the sandstones is concealed by a great quantity of calcareous tufa, on a high cliff of which the district bungalow is built.

Western part.

Towards the western end of the Kahún plateau the lower beds of the tertiary sandstones rise upon the limestones, become horizontal, and bend over,—dipping gently to the south, forming strongly scarped hills, with heights over 3,000 feet. A brine-spring is reported to exist among these hills, but my guide could not point it out.

To the west of Dilwál (the largest village upon the plateau), and very much in the strike of the Choya tertiary sandstone synclinal, are two isolated patches of these beds, let down by faults into depressions of the escarpment above the western arm of the Makrách valley.

Southern escarpment.

The southern escarpment of this (Kahún) plateau extends from Choya-Saidan to Khárdér, projecting so as to form a very open angle between the two branches of the Makrách defile, south of Dilwál. At the head of the Gámthála glen, near Choya, it presents a fine cliff-section of the series, from the "purple sandstone" up to the "nummulitic limestone," including the "salt-crystal zone" (see section, fig. 20, Pl. XVI). The cliffs continue, but the section changes; and within a mile and a half of the mouth of this glen the salt-marl appears, so that the following succession is seen—

			Feet.
Group No. 11.	Nummulitic limestone, lumpy below, more than	...	200
&	(Talus, place of coal shales, &c.)		
,, No. 10.	White, red and purple sandstones and olive metamorphic-pebble conglomerates, estimated ...	...	150

			Feet.
Group No	3.	Red "salt-crystal zone," flaggy and shaly layers ...	40
" No.	4.	Light-coloured semi-calcareous sandstones of magnesian sandstone series	200
" No.	3.	Dark micaceous shaly band, part flaggy ...	100 to 150
" No.	2.	Purple sandstones, flaggy, earthy and shaly below	200 to 300
" No.	1.	Purple and red gypseous marl—seen	150

Further to the westward the succession is different; the "olive group," so strong in the neighbourhood of Choya-Saidan, is still present, but much thinner, and the "salt-crystal zone" disappears, giving place to another rock-group. The magnesian sandstone is no longer of uniform character, but becomes, as it were, blended with the silurian zone, by the presence of other dark shaly bands, which render the distinctive character of the sandstone group less apparent.

The purple sandstone and the underlying salt-marl retain their characters unaltered. Sandstones and shales of the magnesian and silurian groups, however, continue to the westward; the latter extending beyond the former, and, in the absence of the stronger sandstones, presenting still the character of the lower group (silurian).

The new zone, No. 5, increases in thickness rapidly to the west, the salt-pseudomorph zone is not met with again, but the "olive group," much diminished in thickness and somewhat altered in appearance, holds on westward, maintaining its place just beneath the nummulitic rocks.

Makrách glen.

Around the glen of Makrách the cliff-sections exhibit some local differences, most marked along the southern edge of the Kahún plateau. One of these sections has just been given, and the following will serve to show their variation in the vicinity:—

Groups.			Feet.
No. 11.—	Nummulitic limestone, compact above, marly and nodular below ...		200
	(Talus and debris, concealing 50 feet and upwards)		75 ?
No. 10.—	Yellow nodular marls, no nummulites, some corals ...		
	Green glauconitic sandstones, with a few pebbles of crystalline rocks, hæmatitic below: contain *Terebratula* ...	5 to 10	60
	Nodular pseudo-conglomeratic bands; calcareous, friable, light-coloured, flaggy, striped, micaceous sandstones, with black shaly partings	50	

Groups.		Feet.
No. 5.—	Reddish and white, coarse, speckled sandstones, thick-bedded, with red shaly alternations	80
No. 4.—	Greenish and white sandstones, with black shales; sometimes coaly, pyritous and ferruginous nodules large and numerous; fucoids on surfaces ... ... Lumpy, gravelly, conglomerate; pebbles of crystalline rocks ...	200
No. 3.—	Dark shaly beds	100
No. 2.—	Dark red or purple sandstone, alternating below with layers of red shale; generally earthy beneath, near junction with next group	250
No. 1.—	Gypseous, red salt-marl	300

Nearly below the old Makrách customs-bungalow standing on the cliff edge, there is a thin band of red flaggy sandstone, apparently at the base of No. 10 in the above section, which may possibly be one of the last remnants of the salt-crystal zone, No. 8. Some other thin red rocks have been before mentioned high in the series, on the opposite side of the glen, under Níla, and eastward; but in the sections to the west all traces of this band are unknown.

West branch of glen.

In the western branch of the Makrách glen, along which a fault appears to pass towards Kalar-Kahár, the sections are in places concealed by slips and by accumulations of calcareous tufa, as near Málkána; but light-coloured sandstone beds, of the aspect of the magnesian group, still divide the series. Dark shales occur both above and below these sandstone beds, the upper band, of about fifty feet, having some six alternations of sandstone and shale. The sandstones were estimated at from 250 to 300 feet, and the dark shales below at 100 feet. Underneath the latter are, first, the "purple sandstone," and then the "red salt-marl." Over the light-coloured sandstones is as great a thickness of coarse white, reddish and speckled, strong-bedded sandstone, with red shaly layers. This is group No. 5. Above it the talus of the nummulitic limestone cliff greatly conceals the beds, but there is room for both the coal-shales and the diminished "olive group."

Salt-marl.

The red salt-marl occupies the whole interior of the Makrách valley, and the gorge which leads from it south-westwards. Small portions of the marl occur in the

Gámthála glen, and it extends for two miles up the Khárdér branch. The marl, as usual, is gypseous; its upper portion towards the mouth of the gorge, under Níla cliffs, presents some of the most distinct stratification to be found in the group; the gypseous interlaminations, to which the stratified appearance is due, dip, like the rest of the cliff, to the south-east at 35° to 40°.

Mines.

Large salt-mines were once opened in this Makrách glen, but have long since been closed, the miners working now at Khewra. It appears from Dr. Warth's* report that, west of the miners' old village, there is a band of salt, 150 feet thick, including several small layers of marl, the whole dipping at a high angle to the north. At another mine, to the south-west of the old village, the salt beds are thinner, an upper one being twelve feet thick, and consisting of a mixture of white granular salt and two-inch cubes. An old mine is also said to exist in the Gámthála gorge, but none are known in the Khárdér branch. It will be seen from this that, while the general situation of the salt is much the same, its section cannot be closely identified with that of the Khewra set of beds.

Faults.

The great eastern fault of the range bends here, or two faults meet, one coming down each branch of the glen. The dislocation caused by these faults is everywhere irregular. Its effects in the Gámthála glen will be seen in the section, fig. 20, Plate XVI; but in the Khárdér ravine the only result seems to be that the strata to the south-west are left at a rather higher level than those on the opposite side of the glen; while higher up, about Khárdér itself, the beds on both sides being of the same limestone, there is little or no apparent "heave" on one side or the other.

The fractures, which have allowed some of the tertiary sandstones to subside among the limestones and other beds of the north-eastern

* Report, 1871, page 212.

cliffs of this valley, differ entirely in direction from the main break, but may be branches from it, running more east and west. Their throw is not considerable.

There may possibly be some connection between the "line of weakness" along which these faults took place, and the reputed prevalence of earthquakes about Dilwál. One of these is said to have destroyed the Salt Officer's old bungalow on the cliff edge, only the northern half of which, forming a poor habitation, was standing when I visited the place.

SECTION VIII.—MALÔT TABLE-LAND.

Described.

The Malôt table-land is a lofty and broken rocky spur, parallel with the Khárdér branch of the Makrách glen, and rising between it and the plains. The south-eastern portion undulates much, while in the opposite direction the ground slopes gently eastward from the Simbal escarpment, overlooking the Sardi gorge;* northward, towards Kandoya, the plateau undulates, is hilly, or slopes to the north-westward.

Nummulitic limestone.

The upper portion of this table-land is occupied by the light grey nummulitic limestone, differing but little from that of the Dilwál and Kahún country, except that it is perhaps less cherty. Its fossils are, as in other places, chiefly casts of large Gastropods and bivalves with some large Echinoderms, all in an imperfect state. The cliffs which bound this plateau to the southward and west are more lofty and bold than those to the eastward; and the thickness of the limestone, with some allowance for denudation, may be assumed at 250 to 350 or even 400 feet. Parts of the escarpment sometimes seem, as at Malôt, to have slipped downwards between small parallel fissures or faults.

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* This gorge is generally known by the first name, and the salt mines are spoken of as the Sardi mines. Dr. Fleming calls it the "Seral" gorge (p. 241), and natives of the country spoke of it as the Seriárik Wán.

All along these southern cliffs the sections are much confused by land-slips, and the rocks are for large spaces concealed by debris. The talus at the cliff foot conceals the beds next below the nummulitic limestone, but the strong-bedded sandstones of No. 5 (already much thicker) generally project, skirting the base of the limestone cliffs, or forming under-cliffs themselves; further out upon the spurs are broad patches of the nummulitic limestone which have subsided to lower levels, and then beneath these the reddish, or white, or speckled, sandstones of No. 5 are sometimes seen: but the slopes are often covered with quantities of debris derived from the light-coloured sandstones, &c., of group No. 4. The black shaly lower portion of these beds or the representative of group No. 3 is seen occasionally; and below all there is generally a well-marked strong feature formed by the purple sandstone group overlying the red salt-marl.

Cliffs.

Under-cliffs.

In this marl salt is known to occur in several places, and old mines exist in a broad valley due south of the village of Vádála on the edge of the plateau above. The mines being closed, no information could be obtained about them on the ground; but they are noticed in Dr. Warth's Report for 1870-71 (previously quoted), in which he mentions a resemblance between the arrangement of the salt and salt-marl at this place and that at Khewra,—"the white and red gypseous marl overlying the salt, which is underlaid by compact salt-marl." He also gives a rough sketch showing several alternations of red and grey salt with brick-red gypsum, in a vertical position; and he mentions one of many dislocations and disturbances by which the salt and gypsum seem to overlie the superior strata. From the arrangement of the guard-posts in this glen, it is evident that the salt lies in the upper portion of the marl, conforming to the outcrop of the purple sandstone. In the Karúli glen, again, westward of the last, where slips are also common, extensive but concealed deposits of salt are said to exist.

Salt.

The sections of these southern cliffs and spurs are very unsatisfactory; towards the south-east end of the scarp they resemble the section west of Makrách. In other directions the sandstone group No. 5 appears to have increased, being from 250 to 300 feet thick.

Karúli glen.

In the Karúli glen, the red marl may be exposed to a depth of from 460 to more than 500 feet; numerous appearances of discordance caused by slips from above occur in the overlying strata. The purple sandstone above the marl is about 300 feet thick, and at one spot contains, just at its upper limit, a thin band of granular red hæmatite. A commanding and rather detached peak of about 900 feet altitude shows a large portion of the series horizontally bedded, the upper half being formed of light-coloured massive sandstones, with a dark shaly band at their base, resting on the purple sandstone; the whole being capped by some of the reddish sandstone of No. 5.

Malôt sandstones.

Underneath Malôt, at the head of this glen, there are vertical cliffs showing sections at least 300 feet thick of the light-coloured, speckled, and reddish sandstones of the last-named group (No. 5), alternating eight times with bands of red and crimson shale, and overlying brownish sandstone, or sometimes conglomeratic bands, probably the locally uppermost portion of the group No. 4. Within this thickness of sandstones, &c., there is some diversity; the majority of the beds are whitish, some greenish or purple or darkly speckled, some are soft, and some silicious and ferruginous. All varieties of sandy lamination occur in them, and all are much ripple-marked, the red colour which pervades them being less apparent on the freshly broken than on weathered surfaces.

Overlying beds.

Above this group are whitish flags with black filmy layers, and some few bands of greenish shale, with marks like worm-tracks, these beds becoming gravelly and conglomeratic with metamorphic pebbles in a soft olive sandstone matrix. At irregular positions in the upper part of these beds are also

some very red shaly bands, and higher up, the coal shales, below the mass of the nummulitic limestone, are seen just under the village of Karúli in the subsided portion of the cliff on which this village stands. The section is thus—

Coal.

	Feet.
6. Lumpy white limestone, part of a cliff of more than	130
5. Black coaly shales, with much pyrites	0 to 34
(In these coal-shales is a lenticular mass of limestone from 18 inches to 3 feet thick).	
4. Lumpy limestone	6 to 8
3. Black shale	5
2. Hæmatitic and lateritic band	3 to 30
1. Red and pale purple, and ferruginous shale, with plant fragments	30

The coal is merely in strings and lenticular layers in the shale. Some of it was tried in my tent-stove at night, but the fumes were too sulphurous to be borne. The general section near Karúli is as follows:—

Groups.		Feet.
No. 11	Nummulitic limestone, lumpy and cherty below	300
	Coal-shales	20
	Lateritic band, hæmatitic clay	3 to 30
No. 10	Pale purple clay or shale	15
	White flaggy beds, with black filmy layers and beds of red clay ... ... / Olive conglomerate and conglomeratic sandstone ...	30
No. 5.	Reddish, speckled and whitish sandstone with many alternations of red shale	300
No. 4.	Light coloured, flaggy and strong sandstone	250
No. 3.	Black, clunchy, micaceous shales, parts flaggy	100
No. 2.	Purple sandstone, marly below	300
No. 1.	Red salt-marl—seen	300 to 500

The great gorge of Sardi (or the Seriárik Wán), west of Karúli, is cut back into the plateau country for a distance of six and a half miles from the plains in a northerly direction; three miles more of excavation would have carried it right across the whole range. Its depth is not marked upon the map, but appears from aneroid observation to be from 1,500 to 1,600 feet.

Sardi.

The sides of the gorge expose high cliff-sections from the nummulitic limestone downwards to the red salt-marl, which runs up the glen for a distance of nearly five miles. It is evidently the horizontal disposition of the strata that leads to the exposure of the salt-marl, so far up this and other glens intersecting the plateau-country, which is itself a result of the horizontality of the bedding between the southern escarpment and the line along which the rocks assume a northerly dip.

Cliffs.

As noticed by Dr. Fleming and others, with regard to this gorge, the strata have a low dip from the valley towards the east and west; and, as Dr. Warth has observed, there are masses of brick-red gypseous marl on the east side of the glen, near the mines, which are unrepresented at its western side. This can hardly be accounted for except by slipping or by supposed lenticular irregularity in the stratification of the upper part of the marl. Disappearance of the salt beds by solution should have caused a smaller development of the whole group on the eastern side of the glen, and faulting would not be tenable on the presumption that the beds of salt and gypsum retain the arrangement attributed to them, at Khewra and elsewhere, by Dr. Warth. There is, however, another and more feasible explanation of the difficulty; for, to the westward of the mines, a great land-slip has taken place; a tract of the nummulitic limestone, two and a half miles long, having subsided from its continuation with that of the cliffs of Marjhang. In consequence of this dislocation, which can hardly be supposed limited only to the nummulitic limestones, the underlying strata appear to have been pushed out over the marl, so as to conceal the portion of the latter which is really uppermost in the vicinity of the mines; and the salt beds of Sardi, if on nearly the same horizon as those of Khewra and south of Vádála, would seem to have above them a local development of the gypseous red marl unknown in those localities.

Anticlinal.

Land-slip, concealing part of section.

As is often the case with regard to slipped masses along the escarpment, that under Marjhang, although it is broken and confused, and

the ground is often concealed by debris, does not seem to repeat the series regularly. From anterior or subsequent landslip portions of the same limestone mass rest on different groups of the older rock.

Salt.

The thickness of the salt beds mined at Sardi does not seem to be known; one bed of 20 feet, with a north-westerly strike, is mentioned by Dr. Warth; another of the same thickness, but of bad salt, dips at a steep angle to the north-north-west; while good salt above the latter is shown for some 40 feet, and below for about 75 feet, in thickness. There has alwaysb een difficulty in working these mines on account of their low situation, the excavations leading downwards below the level of the stream, and consequently rendering them liable to flooding. The small bi-pyramidal quartz-crystals mentioned as occurring in the gypsum here by Dr. Fleming (*l. c.* p. 251) were stated by people knowing the locality to occur but very rarely.

Sections.

The sections on both sides of the gorge are very much the same, except that, at the head of the glen, the nummulitic limestone suddenly increases in thickness owing to the introduction of a quantity of soft marly beds below, nearly double the depth of the same group, at the sides of the glen, midway between the head and the mouth. That the group has not been reduced at the latter place to any great extent by denudation would appear from the occurrence of the conformable tertiary sandstones, &c., close to the edge of the cliff at the village of Sardi.

The general section exposed in the glen where the rocks are not confused by dislocation or concealed by debris is as follows:—

Groups.		Feet.
No. 12.	Tertiary sandstones close to the edge of cliff to the west of glen	?
No. 11.	Nummulitic limestone, grey, compact, and lumpy, or marly below	250 to 400
	(Talus and debris, room for	150)
No. 5.	Shales and clays, light lavender or darker coloured ...	80
	Sandstones, speckled, ferruginous, and whitish, with red clay or shale bands	250 to 300

Groups.		Feet.
No. 4.	Brownish and light coloured or grey sandstones, passing into—	150 to 200
No. 3.	Black shaly band	80 to 100
No. 2.	Purple sandstone, shaly or marly below	250
No. 1.	Red salt-marl	

The outcrops round the glen are nearly horizontal, the beds dipping gently away from the excavation to the east and west; but at the head of the glen they dip at 20° and 25° to the north. Just beneath the nummulitic limestone talus on the road from Karúli to the Sardi salt mines, a mass of variegated, hæmatitic, earthy laterite, projects. From this rock, it is supposed, the native artificers procure the material which they cut into letter-weights, &c., for sale. In several parts of the Sardi glen there are deposits of calcareous tufa.

Variegated striped beds.

On the hilly part of the plateau above the northern end of the ravine, there are some peculiarly veined concretionary beds high up in the nummulitic limestone. They are of a reddish grey tint, the structure being marked by irregularly concentric rings and thin bands of purple and yellow colour; their thickness is at most 20 feet. From these are taken those parts in which the lines are most strongly developed, for knife handles, weights, and such ornamental uses. The exposed parts of the beds are much jointed, but, if large blocks could be obtained, they would doubtless work up into a pretty marble. It is said that the church at Sháhpur is flagged with stone obtained from this place, and the remains of old quarries are visible.*

Tertiary sandstone.

Close to the locality at which these beds occur, there are some remnants of the tertiary sandstones, and one considerable outlier forming hilly ground; here the lower beds contain a number of reptilian remains and some fossil wood. Bones are numerous, and parts of the heads of crocodiles have been found; but none of the fossils discovered were in very perfect preservation. Due north of this outlier, the underlying limestone rolls up and

* The polished specimens of this stone sent to the museum at Calcutta were presented by Mr. Marshall, late of the Salt Department, Sardi.

then turns steeply down northward, forming the hills south of the picturesque neighbourhood of Kalar-Kahár.

Kalar-Kahár junction of nummulitic and tertiary sandstones, &c.

By the road from Sardi to Kalar-Kahár, both the uppermost nummulitic beds and the lowest tertiary sandstones can be seen. The junction beds of the latter are at most a couple of feet in thickness, and are of pseudo-conglomerate, calcareous and lumpy, and of a greyish purple colour. Sections of small concretions resemble Nummulites; and a few of the latter are scattered through the rock, but whether originally belonging to it, or derived, there is nothing to show, and the junction presents every appearance of conformity. In some places, this junction rock appears more conglomeratic, with pebbles of a dun-coloured limestone, and overlies some 15 feet of purple marly rock, directly under which is the nummulitic limestone. This limestone dips at 35° and 40° to the north on the hill side, and appears to be cut off by a small fault bringing it against the sandstones, &c., close by, west of the descent to the Kalar-Káhár bungalow.

Salt-marl.

The bungalow at this place seems to stand upon an exposure of the red salt-marl, which, strange to say, is seen in connection with the nummulitic limestone, in a hillock over the shore of the lake just east of the bungalow, and is again seen among the gardens and vineyards near the police station to the west. The place abounds with fresh-water springs, which probably indicate faulting of the rocks and exhaustion of any saline impregnation near their sources.

Some brine-springs, however, issue from the marl close by the fœtid black muddy shore of the lake. Tracing this marl to the eastward, it is found at first between the limestone and the tertiary sandstone beds, but afterwards turning to the southward between apparently nearly vertical walls of the limestone, in a direction which would exactly coincide with the run of the fault up the Khárdér arm of the Makrách glen. The marl is so weathered, recomposed, and cemented by calcareous infiltrations, that it is very hard to get a decent specimen of it, but its

internal colour and the association of gypsum identify it with that of the south side of the range.

At its last exposure in the Makrách direction, there are associated with the marl a few beds of friable, whitish and reddish, or purplish sandstones, probably of group No. 5, dipping to the northwards on that side of the marl at about 35°, and the upper portion of these beds is dark and shaly. The limestone on both sides of the marl dips also northwards, or east of north, at nearly the same angle, and the whole exposure has a width of a hundred feet or so. From the occurrence of these few beds of sandstone, it may be presumed that the marl (the softest rock of the series) was forced by pressure into an open fissure caused by disturbance along the western continuation of the Makrách and Choya fault. The water which flows by this fissure from the salt or salt-marl near the lake, is so strongly saturated, that an ordinary *gurra* full (more than two gallons) boiled down, yields two seers (4 lbs.) of salt, according to the account of the natives, and information supplied by Mr. Màrshall of Sardi. Other springs on the same line of fracture and in the same association are, however, fresh.

Junction with sandstones.

In some places where no limestone intervenes between the marl and the sandstones of the tertiary series, the latter are contorted, contain redder clays than usual, and dip sharply at the fault, while elsewhere, where the limestone does intervene, it is separated from the sandstones by smaller dislocations.

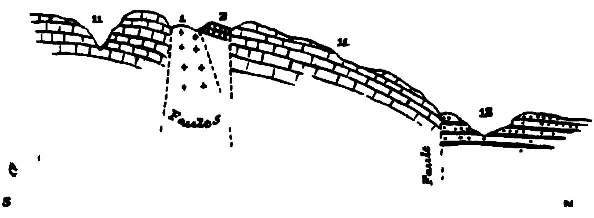


Fig. 23.—Sketch section, S.-N. from Kalar-Kahár.
1—Salt-marl; 2—Sandstones; 11—Nummulitic limestone; 12—Tertiary sandstone series: all faulted.

The remainder of the lower tertiary sandstones in the vicinity are of the usual kind, intercalated with red shales or clays, and the "red clay zone" passes just north of the lake, holding its east and west course along the northern flanks of the hills. Some coal has been mentioned as occurring at a place called Nurwa, north of Kalar-Kahár. This is in the overlying thick, grey, sandstones and orange clays, the coal being merely a few strings of lignite, the fossilized remains of trees or branches, and of no economic value, occurring at the base of a thick band of sandstones.

So called coal.

The Kalar-Kahár lake has a very small catchment area, receiving the surface-water of the hill-slope to the southward, and very little more; a considerable stream with which it is not connected passes close by to the north-east, and another within a mile to the westward. The lake would seem, therefore, to be principally supplied by springs, both fresh and salt, the water from which accumulates in a nearly circular sheet, a mile in diameter, but of only two or three feet in depth, or perhaps four when full.

Kalar-Kahár lake.

In dry weather, the water almost all evaporates, leaving deep black mud covered by a thin saline incrustation. The odour from this mud poisons the air in the vicinity, and, as might be expected, fever is said to be then very rife in the adjacent village.

The salt naturally formed here is impure, of the kind called '*kalar*' by the natives. Five hundred grains of the lake water, according to Dr. Fleming (*l. c.* p. 250), contain 14·97 grains of saline matter, consisting of sulphate of soda and chlorides of sodium and magnesium, with a trace of chloride of calcium.

Its salts.

IX.—Núrpúr Plateau.

This plateau, about twelve miles long by ten broad, presents some variety of structure, the tertiary sandstones overlying a large part of it, as well as being brought into faulted contact, with the limestone beds of the plateau. Faults also

Area; structure.

have caused the re-appearance of the salt-marl in situations as unusual as at Kalar-Kahár.

Tertiary sandstones.

Like other plateaux of the range, the surface undulates much, the northern side being the highest by from 400 to 500 feet. Everywhere, along the northern side, the tertiary sandstones and clays rise upon the flanks of the hills at angles of 20° and 25°, the lower greenish beds having a calculated thickness of 2,500 or 2,600 feet. The red clayey zone still maintains its place along the hill-foot, having very much its normal thickness of about 1,250 feet.

The softer grey sandstones, and drab or orange clays, overlie these, and form the lower ground of the Potwár country. To the north-east, in the vicinity of Kalar-Kahár, the lower beds of the sandstone series rise upon the northern sloping edge of the plateau, and becoming horizontal extend to the southward, occupying a broad, open and nearly circular basin, one part of the edge of which impinges upon the western cliffs of Sardi gorge.

A rough contour-line from this spot marks the boundary of the sandstone basin, the whole of which is occupied by good soil, the waste of these tertiary sandstones and clays, supplemented by rain-wash off the limestone, which rises out from beneath them. At the northern side of the basin the sandstones contain small fragments of bone particularly in pseudo-conglomeratic layers; and many of the beds are covered by patches of white saline efflorescence (*kalar*), which collects along the smaller streams in sufficient quantities to be gathered unmixed with the sand and earth.

Sáheti fault.

A long narrow strip of the tertiary sandstones, 60 to 150 feet in thickness, is let down below the level of the adjoining limestone by a north-west fault from the head of the Nilawán ravine, passing by Sáheti and to the southward of Vasnál. Other denuded outlying masses of these rocks, once doubtless continuous with the faulted portion, overlie

the nummulitic limestone westward of the Nilawán ravine and just above its cliffs*. Near Bhál, almost the very lowest of these beds are red clays, above which bone-fragments occur in the sandstones. The rest of the plateau is mainly occupied by the nummulitic limestone, generally compact, sometimes cherty, and sometimes, as near Vásnál, of a pinkish colour, with red veins. The lower beds are, as usual, nodular, marly, and lumpy. The fossils have a general similarity to those of more easterly situations, but occasionally occur in larger variety and somewhat better preservation, as at the edge of the cliffs overlooking the north-east corner of the Nilawán ravine, where several large *Cypræa*, Echinoderms and other forms are found. From four to five hundred feet may be allowed for the average thicknes of the nummulitic limestone on the eastern half of the plateau, its thickness increasing, however, to the westward.

Thickness of nummulitic limestone.

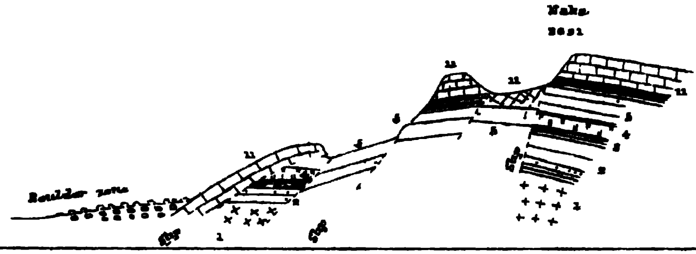
Sar Valley.

The long, narrow, flat valley, in which the village of Sar (or Surr) is situated, coincides in direction with the Sáheti fault. It is occupied by cultivated ground and bounded by broken outcrops of the limestone; but, from the appearance of some reddish sandstone beds in its northern cliffs, it appears very probable that the limestone has been denuded, the floor of the valley being tormed by the sandstones of group No. 5.

Southern edge of plateau and cliffs.

The lofty cliffed escarpment which bounds the Núrpur plateau to the south is very complicated ground, owing to the huge dislocation and irregular and unequal subsidences which have taken place. It is only here and there, at the heads of valleys, that the cliff which rises above the broken ground is of sufficient magnitude to give sections through the whole series, and it

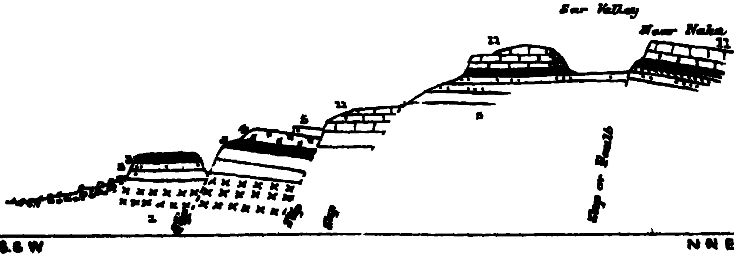
* In one of Dr. Fleming's sections, tertiary sandstone outliers are shown upon both sides of this ravine. Although I crossed the ground where the eastern patch is marked, it may have escaped observation from darkness, and some fields there may be formed of its debris; nor could I see this outlier from higher ground in the neighbourhood commanding the place.



S — N

Fig 29 Diagram to represent dipped face of Escarpment in Section South of Malan

1, Salt marl 2, Purple sandstone 3 Silurian 4 Magnesian Sandstone 5, Speckled Sandstone 11, Nummulitic Limestone



S S W — N N E

Fig 30 Section of dipped ground South of Sar over the Escarpment

1, Salt-marl 2, Purple Sandstone 3, Silurian 4 Magnesian Sandstone 5, Speckled Sandstone 11, Nummulitic Limestone

is always doubtful whether the portions exposed on the spurs and lower eminences are *in situ* or not.

Samli hills and Matán.

In the Samli hills, south of Sardi and near Morghang, the talus of the nummulitic limestone cliffs conceals the beds immediately below them; but a thick band of lilac and variegated clay, very characteristic of the upper part of the "speckled sandstone" group (No. 5) is exposed to a depth of 150 feet, and is even thicker to the westward near Matán. Beneath this are fully 300 feet of the speckled reddish sandstones, some of which are used for mill-stones, they are less alternated with red shale bands than to the eastward; a few of the rocks are white and conglomeratic, with hard quartzose and crystalline-rock pebbles, and ripple-marks are very common on the surfaces of the finer beds.

The magnesian sandstone group is also represented by about 150 feet of light-coloured sandstones and darker shales, overlying a black shaly zone of 90 feet, representing the silurian band. Under this are 300 feet of the purple sandstone series, and then, at the base of all, the salt-marl is seen.

Tendency to dip towards plain.

In this neghbourhood, the rocks beyond the escarpment have a slight tendency to dip towards the plains, but they have all been so affected by slips that this appearance cannot be trusted as original. Over the lower hills, the harder grey sandstones and their fragments are more exposed than in the cliffs, while great masses of the nummulitic limestone and other beds have been transplaced, in some instances having slipped down to the very foot of the hills (see fig. 29, Plate XIX).

Land-slips.

The red marl is seldom seen on the outer sides of these land-slips, along the edge of the boulder-zone, but appears in the valleys between the fallen masses. The lines along which these slips have taken place, though apparent enough upon the surface, can seldom be followed downwards so as to discover their "hade" or throw, and in some cases the only apparent plane of transplacement

is one corresponding with the bedding of the rock, as in the case of outlying patches of the nummulitic limestone (see fig. 30, Plate XIX).

It cannot, of course, be assumed that the lines of slip are as regular or straight as those in the diagrammatic sections figured; the irregularities being concealed, these are only approximate indications.

The general section between the Nilawán and Sardi ravines is thus:—

Groups.		Feet.
No. 11.	Nummulitic limestone, compact above, marly and nodular below (Talus concealing the lower part of it). ..	450
No. 5.	Lavender and variegated clays ...	160
	Reddish and white coarse thick-bedded sandstones, sometimes conglomeratic, generally speckled and ripple-marked, alternating with red clay or shale bands ..	350
No. 4.	Light-coloured and compact sandstones, frequently separated by bands of dark shale ...	150
No. 3.	Black shaly and flaggy band (silurian) ...	90
No. 2.	Purple sandstones, earthy below ...	300
No. 1.	Red, salt-marl, and gypsum ...	?

At a short distance to the eastward of the mouth of the Nilawán ravine, the group No. 4 retains only the light colour which this band generally possesses, the dolomitic character is all but gone, and sandstones, frequently alternating with shaly bands, compose the group, which appears to be losing thickness rapidly towards the west, shales frequently replacing the sandstone portions.

Magnesian sandstone group.

The silurian dark shaly group below has still much of its usual appearance, and occupies its usual position above the purple sandstone.

Silurian.

The grand gorge of the Nilawán (see sections on Plate XX) penetrates this plateau in a northerly direction for a distance of more than five and a half miles, reaching up to Bhálíál near Núrpur. Its depth is estimated at from twelve

Nilawán ravine.

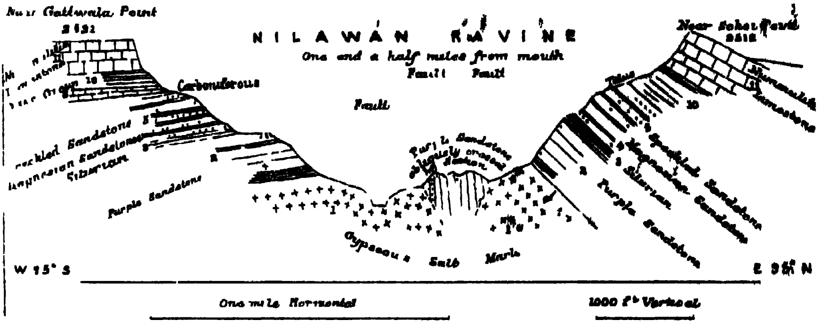


Fig 31

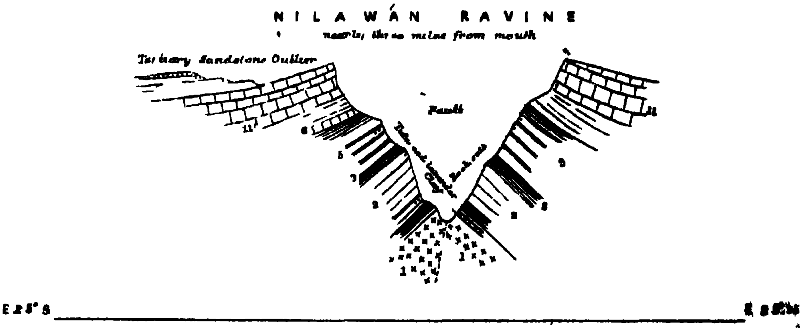


Fig 32

Same scale as the Section above

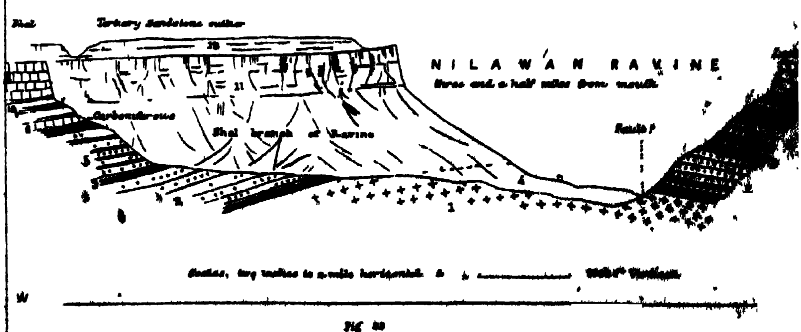


Fig 33

to eighteen hundred feet, and its width, at one place midway up, is only three-quarters of a mile. Just within its mouth is a narrow throat or gorge, entering between high under-cliffs of the purple sandstone group, which approach so closely that there is no room left for the salt marl, although this crops out both before entering and after passing the throat.

Series of Nilawán.

Beyond the narrow portion the ravine opens to a width of more than a mile, and above the purple sandstones of the eastern side, which are fully 400 feet or more in thickness, and of lighter colour towards the top, the dark, lumpy, micaceous shales of the zone No. 3 are seen, with a thickness of 90 or 100 feet. Over this band are 50 feet of light-coloured sandstones, alternating above with three bands of dark shale having a thickness of some 80 or 90 feet, and an aspect very similar to those below. The thick speckled sandstone and red shale group succeeds, and then comes the talus, a high cliff of nummulitic limestone rising above all.

Down in the gorge, just here, and in the narrow part beyond, there is evidence of extreme crushing, and a crooked bifurcating fault occurs, the displacement accompanying which does not appear to be great.

The angle formed by the branching of this fault is occupied by the purple sandstone, on the left bank of the stream vertical, and striking west-north-west to north-west; while on the right bank it is nearly horizontal, dipping at a low angle into the hill.

West side of gorge.

On the western side of the gorge, at the same place, the lower part of the section is, as before mentioned, the purple sandstone, which is somewhat contorted, and the group No. 4 only slightly represented, if at all, but high up beneath the limestone cliffs some of the intervening beds between it and the "speckled sandstone" are exposed, a new member of the series having made its appearance. The same rocks occur also in the Bhál arm of the gorge at right angles to, and on the west side of, the main glen.

Carboniferous in Nilawán ravine.

This new group, which first appears in the Nilawán, is the carboniferous formation, occupying such an important and large place in the geological series to the westward. The section at this place is as follows, chiefly from Dr. Waagen's notes :—

Groups.		Ft.	Ft. Average.
No. 11.	Nummulitic limestone of the plateau, forming a compact limestone; cliff	200	372
	Thin-bedded grey nodular limestone	50	
	Talus, black coaly shales and coal layers	50—60	
	Brown marls with hard concretions, and—*Nummulites* ...	20	
	Hard grey limestone, well bedded	10—15	
	Grey nodular marls with irregular hard layers ...	15	
	Section obscure for 20 feet, blocks of limestone with *Terebratulæ* nearly *in situ*	20	
No. 10.	Dark-green thick sandstone with granules of phosphate of iron, many specimens of large *Nautili*, long slender spines of *Cidaris*, small bivalves and gigantic *Conus*, a foot high (probably cretaceous) ...	15	27
	Pisolitic hæmatite	6	
	Coaly shales, very irregular, with some appearance of discordance to beds below	6	
No. 6.	Coarse sandstone, light yellowish grey, with *Productus spinosus*, bivalves and corals	10	70
	Coaly, sandy shale	10	
	Light greenish sandstone with coaly laminæ, one bed of this sandstone is 20 feet thick	50	
No. 5.	Lavender clay	6	286
	Greenish and blackish shales, many indurated marl beds, containing a yellow mineral (? an ore of lead) ...	60	
	Lavender clay and thick white and yellowish sandstone, interstratified	100	
	Red sandstone	30	
	Lavender clay, dark-coloured	10	
	Red sandstone with many alternations of red and purple shale	80	
Nos. 3, 4.	Soft green sandstones with pebbles of crystalline rocks; Dark shaly band	60—90	75
No. 2.	Purple sandstones (200 feet, seen)	400	470
	Purple shaly lower portion	70	
No. 1.	Red gypseous salt marl.	?	

A little to the northwards the gorge again becomes very narrow, and there is much appearance of crushing, the purple sandstone again approaching on either side so as to leave little or no space to be occupied by the salt-marl; slips from above often conceal the true thickness of the rocks, and the purple sandstone in some sections appears earthy or shaly for nearly half its thickness, but for much less in others.

Group No. 4.

The magnesian group, where separable, has a thickness of more than 50 feet, but the light sandstones are so intercalated with dark shales that they seem rather to form a part of the shaly zone below, the whole hardly amounting to 100 feet. Above this the speckled and red-banded sandstone occurs, but can hardly be seen from the bottom of the narrow gorge, while the talus of the nummulitic limestone cliff obscures the softer beds beneath that zone.

Volcanic rock.

In this narrow part of the gorge, as at Khewra, there is again seen the same sort of volcanic, lavender, ash-like rock with an irregular thickness of a few feet, underlying a gypsum band just at the top of the salt-marl, and associated also with a decomposing layer of the more solid volcanic rock, the same as occurs, in quite a similar situation, at Khewra.

Salt at narrow part of gorge.

Where this narrow part of the gorge opens a little, to the northwards, a 30-feet bed of rock-salt is seen at the surface on the right bank of the stream. It contains thin laminæ of different colour, and forms four or five beds lying quite parallel to the stratification of the overlying purple sandstone close to the base of which it occurs, with a band of the lavender clay just noticed intervening. Rock salt is seen again a little further to the north, with two strongly marked white beds, and a thickness of 60 feet. It is also known to exist in very many other parts of the red marl of this gorge, and the lavender clay and volcanic trap-rock occur pretty generally. The latter was found by Dr. Warth at one spot interposed between some thin layers of bad salt below, and a 30 to 50-feet bed of white gypsum

Other salt mines.

above, just beneath the purple sandstone. The trap here was 15 feet thick, much decomposed, and contained a layer of talc. It would appear that the overlying gypsum band is of irregular thickness, and not constantly present, as at Khewra glen.

Where the narrow part of the gorge opens and joins the southern side of the Bhál ravine, the purple sandstones appear to be faulted along a north-westerly line, and the beds are vertical. This disturbance would also seem to have affected the salt beds in some of the neighbouring mines, where Dr. Warth describes them as likewise vertical, having nearly the same strike and a thickness of 60 feet, two beds of 30 feet each being separated by a 10-feet bed of bad salt.

On the opposite side of the stream in the Bhál gorge, and at a considerable height upon the foot of the spur between this stream and that from Bháliál, other old mines occur, in which the same observer found the rock-salt bearing north and south, nearly vertical, but dipping slightly to the east; and in another mine further northwards the salt beds were disturbed, striking south-east and north-west as far as could be made out.

Disturbance.

Hence it may be inferred that, notwithstanding the prevalence of steady horizontal or inclined stratification, all round the lower portion of the glen the softer salt marl has yielded to disturbance which has left much less impression upon the massive series overlying; the lines of disturbance, too, coincide so nearly with the directions in which the glen has been excavated, as to suggest their having conduced to this result. In both this and the great Sardi glen (the two largest excavations of the kind) it may be

Beds dipping away from this and Sardi glen.

observed that the beds dip away from each side towards the east and west as if there had been formerly an anticlinal arrangement of the strata; but this may with more probability have resulted from other disturbance, accompanied by slight dislocation of the ground out of which the valleys have been eroded. At the heads of both of these large glens the beds dip steeply to the northwards below, but are nearly horizontal above the cliffs, so that

the two glens have a certain amount of stratigraphic resemblance; from this it may be inferred that similarity of conditions induced the denudation to follow certain lines.

Drainage.

The streams in the Nilawán drain by far the largest part of the Núrpur plateau, notwithstanding which the structure of that plateau seems to indicate the former existence of an uptilted rim or edge along the whole of its southern side, which must have been broken through in order to allow the drainage to escape. This might have been effected by a fissure, coinciding with the general course of the glen being either left open or filled with portions of the superincumbent beds, easily removable by denudation. Otherwise, it can only be supposed that the superior height of the limestone and underlying beds at the northern side of the plateau so influenced the general disposition of the formerly overlying tertiary sandstones, &c., that a southerly drainage was initiated. The Sahcti fault with its subsidence of a couple of hundred feet obliquely crossing the direction of this southerly outflow may have increased the tendency, or, if continued along the course of the future Nilawán, may have depressed a portion of the tilted limestone rim, so as to decide the point at which the erosion of the ravine commenced.*

* In the case of the Sardi ravine, a longitudinal break coinciding with the axis of an anticlinal, or what would otherwise have been an anticlinal curve, seems even more likely to have taken place, for though the general inclinations are lower than down in the narrow part of the Nilawán, there is a very general dip away from the edges of the excavation. The drainage of the Sardi ravine also comes from a small basin to the northward, so small that it seems quite disproportioned to the size of the gorge, and it is possible that much of the eastern part of the Núrpur plateau may have discharged its rainfall into the Sardi ravine before the streams to the northward through the soft tertiary sandstones were deepened sufficiently to lead the water in that direction. Within little more than half a mile to the westward of the latter ravine, a parallel stream to that within it runs due north for nearly four miles, into the small basin above the head of the glen, and none of the water from above the eastern edge of the Sardi glen escarpment, except some small streams about Simbal, finds its way into this catchment basin. Here, too, the progressive destruction of once overlying tertiary sandstones and clays may have led the denudation along the line of the gorge; but if this denudation had acted in the same manner as in many other cases over the plateau country, it would have left the limestone surface of the anticlinal (if this latter existed) almost intact, instead of cutting a deep gorge right along the highest part of it. The probabilities seem all in favour of erosion along fissures, or else of unequal subsidence of the adjacent country around these glens.

Coal.

The tertiary coal and its accompanying shales are seen beneath the high cliff of nummulitic limestone, along the face of which the patrol road has been carried up the ascent which leads out of the northern part of the gorge on to the Núrpur plateau. The coal is in very small quantity, and occurs in the shales.*

Bhál carboniferous.

The sides of the Bhál branch of the Nilawán are much covered by debris below the nummulitic cliffs, but at the head of this part of the ravine, the carboniferous and locally next overlying beds form a ledge on which a confused mass of great limestone blocks rest, concealing the basal portion of the nummulitic series. The way to this exposure lies through a fissure parallel to, and at the very edge of, the cliff south of Bhál. Descending this, the talus at the foot is reached, and a further descent leads to the ledge.

The following is the section here, measured, where practicable, along the bed of the Chellintun stream.†

NUMMULITIC.	13. Nummulitic limestone of cliffs and plateau ... (Fallen blocks concealing the section, place for many feet of rocks).	300 ft. (and upwards.)
CRETACEOUS?	12. Hard shaly calcareous beds	7 "
	11. Sandy dark limestone or highly calcareous beds ...	6 "
	10. Hard sandstone band	1 "
	9. Sandy and lumpy limestone with shark's teeth, *Terebratula* and Echinid spines	4 "
	8. Dark-green ferruginous sandstone	12 "
	7. Pisolitic hæmatite	from 4 to 8 "
	6. Lenticular layer of lavender shale	1 "
	5. White micaceous fine sandstone with black markings ...	15 "
	4. Hard blue sandstone with gypseous clay bands ...	6 "
	3. Soft-green sandstone	4 "
	2. Black shaly and ferruginous sandy beds	4 "

* Dr. Oldham's Memo. "*Mineral Resources, Salt Range, &c.*," previously noticed.

† Visited by Dr. Waagen and myself together and separately. This section is taken chiefly from the notes of the former, as they are more detailed than my own.

CARBONIFEROUS.	1. Hard thick-bedded calcareous sandstone full of fossils, *Belerophon, Productus, Fusulina*, &c., &c. ..	41 ft. (and upwards.)
	More beds of the same group (?) concealed below by a talus.	

Verála scarp.

From the mouth of the Nilawán ravine westward stretches the lofty but greatly concealed Verála scarp In the upper portion of this hardly any rock can be pronounced *in situ* among the masses of debris, but lower down, here and there, small exposures of the red marl, purple sandstone, and next overlying groups occur. Where seen, the rocks appear to have been much affected by dislocation, some of the fractures being probably connected with the large and fine springs of fresh water beneath the escarpment, called the Verála Chashma. Just above these, a portion of the limestone of the plateau has sunk along two small parallel north-north-west faults, through which water percolating and arrested by shaly beds below, might easily burst from the escarpment in the form of springs. In the neighbourhood of these springs many of the fragments are of sandy limestone, full of *Fusulinæ*, Spirifers, Crinoid rings, and other carboniferous fossils, the parent beds of which doubtless exist in the escarpment, and from the quantity of the debris would appear to form a strong band.

Track to Pail.

Along a track leading obliquely up the escarpment from the Verála escarpment to Pail, the dark shaly silurian zone is exposed, and is seen still fully 100 feet in thickness in the face of some fine cliffs to the westward. The beds are micaceous, and more sandy and clunchy than in the east, and they contain conglomeratic bands with pebbles of crystalline rock. Many of the flaggy and thin sandstones are whitish and speckled, their surfaces being covered with ripple-marks and tracks like those of Annelids.

In this neighbourhood, both the purple sandstones below and the speckled sandstones immediately above the silurian beds are largely developed, and of more than usual thickness. Further up the track, near the pass leading on to the plateau, the carboniferous beds show themselves in the escarpment to the right of the road, with a

thickness of about 150 feet. The *Fusulina* band here has a thickness of 12 feet, and overlies some 80 feet of sandy, massive calcareous beds. All the beds within reach of examination here were of very sandy limestone; soft, shaly beds were seen to overlie these, just beneath the nummulitic limestones, but none of the coal shales were visible.

From the crest of this pass towards Pail the path lies through a flat, narrow valley at about the level of the top beds of the carboniferous group; two similar little valleys running off to the west-south-west, and the whole being closed in by considerable hills of undulating nummulitic limestone.

Pail-part of plateau country.

The interval between the Núrpur plateau and the commencement of the Sôn country near Chámil may be considered as an extension of either, or a sort of lower step between the two.

Núrpur.

After descending from the Núrpur country over an escarpment of the nummulitic limestone, the flat, cultivated, long and narrow valley of Badrár is entered, extending in a north-easterly direction towards Vásnál. At the Badrár end the valley is divided into two by some hills of contorted nummulitic limestone, and between that village and Dheri the red gypseous salt-marl forms rounded hillocky ground, without any of the intervening rocks between it and the nummulitic limestone on one side; but on the other, just below the escarpment, some rolling beds of the speckled sandstone group are seen. The dislocations which produced this exposure in such a place must have been both large and complicated, but unfortunately the cultivated flat ground renders it impossible to trace them, or to say which are the rocks in contact with the salt-marl. On one side the nummulitic limestone is steady, dipping at a low angle to the south-east; on the other it is considerably contorted, so as to suggest the existence of a line or lines of fracture, coinciding with the long valley stretching towards Vásnál, and meeting other faults intersecting the main fracture between Dheri and Pail.

At the north-eastern end of this valley there is abundant evidence of faulting, and the ground is greatly broken. One fracture coinciding with the direction of the valley forms the boundary line between the nummulitic limestone and the tertiary sandstones for a distance of nearly three miles. This fault crosses the mouth of the strange little oval valley of Vásnál, surrounded by high cliffs and broken hills of the nummulitic limestone, and occupied within by a mass of the red salt-marl, through which deep gullies and ravines lead out of the valley, beneath the high and conspicuous limestone peak of Tirwár. At the south-west corner of the valley only are there a few ledges of purple and speckled sandstone seen, linking the marl with its proper associates, and these appear to be, like the marl itself, cut off everywhere around the exposure by faults.

Vásnál.

The whole of the marl seen here is little less than a mile in length, and rather more than a quarter of a mile wide, so that it has an area of about a quarter of a square mile. No good salt beds are known to occur here, but in one place an impure saline portion of the marl is 30 feet thick. A strong fresh stream which traverses the marl, after rain, is said to become saline. Any appearance resembling stratification seen in the salt-marl is nearly horizontal, but the limestone surrounding the marl, though also generally horizontally bedded, is in some places a good deal disturbed.

Salt marl.

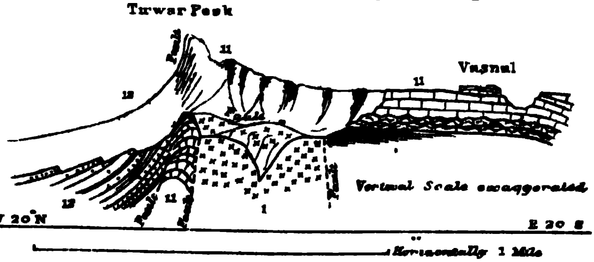


Fig. 24.—Section across Vásnál valley.
1. Salt marl. 11. Nummulitic limestone. 12. Tertiary sandstone.

In one or two spots the debris of some soft shaly beds is seen mixed with some broken portions of the beds above the salt marl, but hardly

in a recognisable state. The lower part of the nummulitic limestone is as usual nodular and lumpy, and among its upper beds about Vásnál village are some peculiar, vesicular, ferruginous, and slaggy-looking layers; pink, compact, and red-veined limestone bands also occur.

The nummulitic limestone on the north-western side of the little valley is quite cut out, under Tirwár peak at the mouth of the glen, by one or other of the faults between which this limestone occurs, and the bedding both here and along the face of the peak is much disturbed, being in places quite vertical. The tertiary sandstones outside are inclined sharply along the fault, but at a little distance assume their usual low northerly dip; the lower part of this group being as usual succeeded by the red clay zone and other overlying beds.

Rocks of Pail country.

Towards Jába to the west-south-west, the dip of the tertiary sandstones is low, becoming more nearly horizontal as the table-land about Pail is reached. The sloping beds rise to this table-land forming a well marked escarpment northwards, overlooking the limestone ground. The basal sandstones are very commonly greenish, and red earthy bands rarely occur. Northwards of Badrár the nummulitic limestones form a broad dome-shaped mass, dipping in all directions; but south-west of this, and north of Pail, the country is a wide level plain, bounded towards the Sôn district by one of those long narrow straight valleys in the nummulitic limestone, which look so much as if they had been excavated upon lines of fault. This valley strikes to the north-north-west, and immediately beyond it, the tertiary sandstones encroach still further upon the plateau ground, and form a mass of horizontally stratified hills.

Fault.

Close to Pail a fault, running a little to the east of north certainly occurs; for some of the tertiary sandstones forming a low ridge, dip towards the carboniferous limestones, which form the northern face of the hills, rising immediately south of the village. Here the carboniferous group has already increased much, the slope of the hills showing a thickness of at least 250 feet of ferruginous, magnesian, and sandy limestones, dipping

south-south-east at 20° and 25°, and the upper beds containing numerous specimens of *Spirifera* and other carboniferous fossils. These beds are overlaid by the nummulitic limestone with a few intervening sandy and shaly layers, some of which may possibly represent the "olive group," or cretaceous beds of the Nilawán ravine. The nummulitic beds are at first parallel with the carboniferous, but soon undulate, and on the southern side of the hill, where they form an escarpment, dip to the northward by west.

Structure of country seen to north.

From the summit of this hill the complicated structure of the surrounding country can be seen to advantage. Northwards is the flat cultivated plain, bounded by the tertiary sandstone escarpment; to the left low undulations of the nummulitic limestone rise gradually from the flat to the margin of the long valley previously mentioned; to the right are swelling hills of the same limestone, and the complications about Badrúr and Dheri (where the salt-marl appears) divided from the Pail hill by cultivated tracts of low ground; while the carboniferous group of this hill itself is covered by nummulitic limestone, and cut off to the west by a fault bringing it against tertiary sandstones. The closer relations of the carboniferous group must be connected with dislocation, but they are concealed by the earthy deposits of the plain below.

To south.

Looking southward, another nummulitic limestone hill, covered by "sonhetta" (*Dodonæa Burmanniana*) jungle is seen, divided from the Pail hill by a deep narrow valley, and by a similar valley from yet another, still further south, the Bieôt hill, composed of the same limestone, which also caps the cliffs westward of the Verála scarp. Both of these hills are formed of undulating and nearly horizontal beds, from which they receive a tabular appearance. To the left hand are the long escarpment lines of the Núrpur plateau, and on the right, nearly in front, a deep open gorge or ravine leading down to the southern plains, from the right hand side of which rises the bold escarpment of the Chámil nummulitic limestone.

At the head of this gorge the beds are all much broken and slipped, and there are signs of water having been dammed up, in some black clays and whitish calcareous sandy beds containing sub-recent marsh shells. Further down, the carboniferous beds protrude from the debris at the foot of the nummulitic cliffs, being still sandy, ferruginous, and calcareous, the most sandy beds occurring at the top and bottom of the exposure. On the talus beneath the cliffs, some dark, gypseous, shaly and hæmatitic masses indicate the presence of the coaly shales near the base of the nummulitic series.

Ravine leading to Katta.

Ledges of the "speckled sandstone" (No. 5) project from beneath the carboniferous group, and the greenish and dark micaceous silurian zone appearing under these speckled sandstones, shows white saline efflorescence; it has still a thickness of a hundred feet or somewhat more. The purple sandstones come out from below this zone, and the section terminates below, as usual, with the red gypseous marl.

From the situation of the latter group at the west or Chámil side of the glen, and the partial absence of the "purple sandstone," it would seem that the Pail fault is continued in this direction. There is also a decided appearance of another fault at right angles to this, crossing the middle of the glen and running eastwards up a deep ravine, so as to bring the lower part of the local series against the red marl.

Near the mouth of the glen the arrangement of the lower rocks is complicated, either by faulting or slips, or both; a mass of the "purple sandstones" being let into the marl longitudinally in the middle of the ravine. The hill rising above the left bank of this ravine exposes the whole local section from the red salt marl up to the nummulitic limestone, including groups 1, 2, 3, 5, 6, 10 and 11; but these are much confused by landslips, particularly on the south or outer side of the hill.

East of the mouth of ravine.

The ground to the right slopes much more gradually southwards towards the plains from Chámil scarp, and is greatly concealed by masses of coarse debris, very

West of the mouth of ravine.

much of which comes from carboniferous rocks. The "purple sandstones" are seen in gullies, and further up the "speckled sandstones" crop out; but close to the scarp there is but little seen of the carboniferous and overlying beds till the nummulitic limestone, thick and massive, rises in bold cliffs to the edge of the plateau above.

SECTION X.—SÔN PLATEAU.

Situation.

The Sôn Sakesar plateau is the largest and broadest in the whole range: it includes the country about Chámil, Sodhi, the hilly tract near the latter place, to the southward, and the larger area, chiefly occupied by the carboniferous limestone, between the southern escarpment of the range and the Sôn valley proper. The principal place within the plateau is Naoshera, nearly in the centre. The table-land possesses this peculiarity, that while the northern half presents the greatest sameness and simplicity of geological structure (if the formation of the lake basins be excepted), the southern side, particularly beneath the escarpment, is one of the most complicated tracts in the whole range, owing to the heterogeneous disposition of the groups by reason of dislocation, land slips, contortions, and erosion.

Tertiary sandstones and nummulitic limestone.

For 26 miles westward from the Pail country last described, the same relations prevail between the tertiary sandstones and shales and the underlying nummulitic limestone. Within this distance the whole border of the Potwár plateau rises gradually, and throughout most of it the plateau of the range and that to the north are separated by a less marked and less abrupt declivity than usual.

The tertiary sandstone ground being high, its excavation, where formed of the softer sandstones, &c., into gullies, ravines, and *khuddera*, has necessarily been extreme; this *khuddera* ground always ending at the boundary of the nummulitic limestone. About Jába where the softer beds encroach upon the limestone, more or less horizontality of stratification obtains; but further west, steeper, yet still

gentle, northerly inclinations at angles of 15°, 20°, and 30° carry the lower beds of the sandstone, &c., from the flanks of a long anticlinal of the nummulitic limestone, beneath the red, shaly, and clayey, tertiary band, above which the grey sandstones and orange clays of the next portion of that series constantly occur.

In the Jába country the lower sandstones are very often of a greenish or grey colour and thick-bedded, sometimes pebbly, and with but few red bands. Calcareous pseudo-conglomerates occur, also a few beds of greyish shale, and some concretionary beds, from which the small nodules weather out and strew the ground. The same characteristics, with slight and local variation, extend everywhere throughout the group on the northern flanks of the range.

Rock-tar.

Either in the nummulitic limestone at the base of the sandstones, or in the lower 30 feet of the latter, traces of petroleum or rock-tar, in very small quantities, are to be found at three or four localities on the northern flanks of the Sôn plateau. These places are,—three and a half miles north-east of Kabaki, two and a half miles north-west of Dhuddhur; two and a half miles north-west of Mardowál; and a questionable locality a couple of miles east of a salt chowki situated northwards of Sakesar mountain.* Petroleum also occurs southward of this mountain in an outlying fragment of the sandstone beds. The quantities issuing from the rocks are small and worthless as sources of supply, but being found both in the uppermost beds of the limestone, and in the lowest of the overlying sandstones, the occurrence of this mineral oil may perhaps indicate continuity of deposition of these groups, rather than the existence of any marked break between them.

The width of the lower sandstone and clay band is in many places greater than usual, but its thickness probably does not average more than 1,500 feet.† The red earthy zone above may be rather more than

* See Report on the Punjab Oil Lands by Mr. B. S. Lyman, pages 43 to 46.

† Nearly 1,000 feet greater than at the eastern end of the range.

1,000 feet thick, but its upper and lower limits are not sharply defined, and the orange and grey overlying rocks must be enormously thick, extending far into the Potwár with northerly inclinations.

Nummulitic.

The nummulitic limestone has everywhere the same aspect, the same prominent light colour, compact and sometimes cherty texture above, but is always nodular and lumpy below; soft and marly between the nodules, and of a warm yellowish colour. Its fossils also are still the imperfect casts of bivalves, large Gastropods, and Echinoderms and Nummulites throughout. It extends everywhere over the northern half of the plateau with a most irregular southern boundary, and occurs also as outlying masses.

The increased contortion of the beds in this portion of the range becomes apparent even on the plateau, where the nummulitic beds roll along numerous east and west anticlinal axes, in bold, open or closer curves, which very generally coincide with the features of the ground, and sometimes form considerable hills.

The country which exhibits most of this north and south compression is that around Sodhi. Along the valley of the Nursingphoár river and to the south, for some distance, a long rugged hilly strip of nummulitic rocks similarly contorted stretches from this Sodhi vicinity towards Sakesar, roughly dividing the plateau into nearly equal parts; while on the northern side of the table-land the limestone beds roll up in a great wave, some two miles wide, and then turning over to the northward, rapidly disappear beneath the sandstone series.

The southern edge of the nummulitic limestone usually forms a bold escarpment with a gentle northerly inclination for some distance, and, unlike the Núrpur plateau, the northern side of this Sôn plateau is rather lower than the south, as a general rule. Numerous large and small outliers of the nummulitic rocks, frequently connected with dislocation, are to be found beyond its general southern escarpment, which maintains a very irregularly indented east and west direction.

At the western end of the plateau the nummulitic limestone beds rise rapidly with the broad anticlinal wave on the Potwár side, and form the summit and steeper acclivities of Sakesar mountain. Its thickness over the whole plateau may average 500 feet.

Carboniferous.

South of the east-and-west dividing ridge, and extending further westward than the Sôn country, is a wide, elevated, and greatly undulating tract,* formed chiefly of the carboniferous limestone, which has here its largest exposure. Deep valleys and ravines intersect this ground, all leading out upon the plains to the south, and all of them showing more or less perfectly the succession of the underlying rocks.

Triassic and Jura.

In this country two new groups enter the series, and two which have continued hitherto from the east disappear. The first which dies out is the cretaceous or "olive group,"† then the dark shaly silurian band. Within two and a half miles or so of the place where the former disappears, the triassic beds begin to show themselves, and ten miles further westward, these are overlaid by the commencement of the jurassic group, the only one wanting to make up the full number of the Salt Range sub-divisions and formations.

Nursingphoár.

Near where the valley from Pail towards Katta opens on the plain, but a little to the westward, is the mouth of the Nursingphoár defile, a deep cut, through which the stream from Sodhi escapes. Down in the bottom of this gorge, and a mile or more from the mouth of it, the red salt-marl appears, but is so slightly saline as not to render the water of the stream unfit for drinking. The groups above the marl are seen on both sides of the glen, first the "purple sandstone," lighter coloured at top; then the dark shaly silurian band, here about 80 feet in thickness, or rather more. Group

* The "Patiál hills."

† Some beds doubtfully representing this group occur far to the westward at one spot, on the Katwahi road to Sháhpur.

J. Schaumburg, Lith.

CLIFF AT CHAMIL COAL LOCALITY

No. 4 is no longer present. The coarse and often conglomeratic sandstones of group No. 5 are strongly developed and overlaid by nearly 180 feet of the upper lavender-coloured clays, the whole group considerably exceeding 300 feet. Above this is No. 6, the carboniferous group, limestones, &c., quite 300 feet or more thick, and the nummulitic limestones as usual form the high cliffs of the escarpments, having a thickness of about 300 feet also. A considerable fault extends along the

Fault.

glen and turns with it above Nursingphoár. This fault has displaced a portion of the northern side of an east-and-west anticlinal curve, formed by the groups Nos. 2, 3 and 4, in the cliffs opposite to the Pír—a sacred and picturesque locality where there are fine springs overlooked by some Fakírs' residence and temple perched upon a ledge more than half way up the cliffs.

Coal shales, &c.

On the left side of the glen the stream from the Chámil part of the plateau falls over the lofty vertical limestone cliffs of the escarpment into a small rock-basin, the sides of which expose a section in the basal beds of the nummulitic group (fig. 35, Plate XXI). The readings of the aneroid barometer (uncorrected for temperature), indicated a difference in elevation between the basin and the cliff-edge above of more than 500 feet, most of this being made up of the following section :—*

		Ft.	In	Ft.	In.
NUMMULITIC ...	Compact nummulitic limestone in two bands ...	200	0		
	A thin shaly band	10	0		
	Thick limestone	28	0		
	Earthy, thin-bedded, lumpy, and shaly limestone ...	50	0		
				288	0
	Black shales, part sandy, with a few coaly layers below	20	0		
	Sandy and shaly beds of dark or ferruginous colour, with pyrites	8	0		
	Coal from 6 inches to a foot	0	9		
	Black sandy bed, carbonaceous and pyritous ...	1	6		
	Black shales	2	0		
	Coal	0	6		

* Part of this section also appears in Dr. Oldham's paper, "On the Mineral Resources of the Salt Range, Bannu and Kohát districts;" previously noticed.

		Ft.	In.	Ft.	In.
NUMMULITIC,—(*continued.*)	Black, sandy, and lumpy shales, ferruginous and pyritous	7	6		
	Black shales, friable	3	6		
	Hard calcareous sandstone	2	6		
	Dark shales	3	0		
	Hard calcareous sandstone	1	0		
	Sandy shale	3	0		
				53	3
	Lumpy dark-coloured limestone; *Nummulites* ...	45	0		
				45	0
CARBONIFEROUS...	Greenish-grey calcareous sandstone	35	0		
	Ferruginous calcareous beds	15	0		
	Grey limestone	45	0		
	Calcareous beds with three beds of black shale, the thickest 3 feet	20	0		
				115	0

The uppermost part of the greenish-grey calcareous sandstones may represent the cretaceous series, but there is nothing here to warrant their separation from the strata beneath them. Other rocks of the carboniferous formation project below those of the above list, and the speckled sandstone group could be seen from above; but the cliffs formed by the lower part of the series were too precipitous to descend to the place of its exposure.

Further into the defile.

Further to the west and still on the left side of the ravine below the temple of Nursingphoár, the following section was noted by Dr. Waagen:—

		Ft.
NUMMULITIC ...	Part of the strong nummulitic limestone	50
	Yellow calcareous marl and marly limestone	50
	Grayish-yellow marls with numerous *Nummulites*, also *Fusus* and other fossils	15
	Black coaly shale	20
	Brown sandstone with small *Nummulites*	2 to 3
	Variegated sandstones with interlaminated shales, also variegated	15
CRETACEOUS ...	Brownish-yellow limestones and calcareous marly beds with *Terebratula Flemingii*, *Ostrea*, and Echinids ...	20
	Hæmatite, partly changing into pisolitic iron ore ...	10

		Ft.
CARBONIFEROUS ..	Thin-bedded limestone with intercalations of black coaly shale; contains many carboniferous fossils. It changes into compact limestone, on the upper surface cavernous and corroded	200

The carboniferous rocks are faulted here, and seen in the stream bed at the foot of the cliff.

Right side of glen.

Further down the glen on its right-hand side, a stream course enters from the west showing a little of the red salt-marl and some slipping and crushing of the overlying rocks. The purple sandstones here appeared to contain, at the top of the group, a 50-feet bed of coarse conglomerate, the pebbles being all of old crystalline or metamorphic rocks. The dark, shaly silurian band is much obliquely laminated, contains fine black and white ribband layers of sandy shale with hæmatitic nodules and some sandstone bands, the whole group having a greenish aspect. Thick and thin bedded speckled sandstones succeed, and are overlaid, first by the carboniferous and then by the nummulitic group stretching along the glen side up towards Nursingphoár. On this side of the glen, just after passing the gap through which the river crosses the "purple sandstone," Dr. Waagen found greenish thin-bedded soft sandstones, partly coaly, with a thick band of conglomerate of crystalline pebbles, the group being about 50 feet in thickness, and most probably the same as that just now noticed. Above this succeeded a great mass of thin-bedded reddish sandstones and red shales, over which came about 100 feet of lavender clay, with sandstone and marlstone layers. In its upper part this lavender clay became coaly and black, and was overlaid by yellow and grey sandstones with *Bellerophon*, *productus*, &c., of the carboniferous group. The lavender clays, hitherto very thick at the top of the "speckled and reddish sandstone" series, here begin to grow thinner, but they are often subject to local variation in this respect.

Above Nursingphoár.

Further up the stream than Nursingphoár, and just where it bends from west to south-east, the fault is seen bringing the nummulitic and carboniferous beds discordantly

together; the former only slightly fossiliferous, but containing in places numbers of globular *Foraminifera,* of about the size of peas, and the latter group being varied a good deal along the oblique line of fault at the contact with the newer rock.

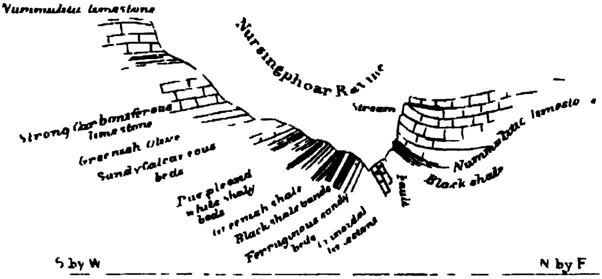


Fig. 36.—Diagramatic section, Nursingphoár Valley.

At this place there are some slight traces of the black coaly shales beneath the nummulitic limestone, while just across the fault crinoidal carboniferous limestone is seen. On the opposite bank of the stream some ferruginous beds dip steeply (at 75°) towards the high ground above, and are overlaid by two black shaly layers of about a foot each, separated by two feet of sandy limestone. Over these are 20 feet of greenish shales, succeeded by 80 feet of purple and white shaly beds, above which come greenish, arenaceous, and argillaceous limestones, the ordinary grey, or bluish, compact, thick carboniferous limestone overlying the whole and passing beneath the talus at the foot of the nummulitic limestones which cap the hill.

Further up the glen.

Somewhat further up the stream, the nummulitic limestone forms the left bank, and on the southern side of the glen white carboniferous, crinoidal limestone dips at a very high angle under a quantity of purple clays, alternating three times in the upper fifty feet with greenish sandy beds. A few hundred yards further, on the same side of the stream, the carboniferous group is formed of 180 to 200 feet of pale pinkish-white sandstones with calcareous beds, containing in the upper part some carbonaceous and mica-

ceous black shaly layers, and near the top a purple clay band. In the sandy limestone-layers crinoid fragments and numbers of small *Fusulinæ* occur, while in the river bed are fallen masses of greenish weathered, calcareous *Spirifer*-sandstones, and sandy beds with large annelid tracks. Still further up the stream the fault crosses it, cutting out the carboniferous beds obliquely in the hill side to the south, and the river runs between steep nummulitic limestone cliffs, exhibiting much crushing and disturbance, the beds being turned upwards towards the fault and dipping at angles as high as 50° from the northern flanks of the hills. The same limestone forms the country as far as Sodhi,* and it extends much beyond this place. Quantities of calcareous tufa fill the gorge southward of the Sodhi bungalow.

Sodhi

At about a mile to the westward of the Upper Katta village, which is situated opposite to the mouth of the Nursingphoár gorge, there is a considerable salt-spring, conspicuous from a distance, on account of the quantity of calcareous tufa which it has deposited. It issues from the "purple sandstone," of which there is rather less than usual here, and the spring seems to come from the lower part of this formation, purple marly and shaly layers being seen in the vicinity.

Katta.

On the hill above this spring the following section is seen (taken from Dr. Waagen's notes), the "olive group" or cretaceous beds being no longer present :—

		Feet.
1.—NUMMULITIC...	Nummulitic limestone capping the hill ...	260 to 300
	NOTE.—Upper surface of carboniferous beds much corroded on uneven surfaces, and white sandstone occurs in pockets covered by hæmatite.	

* There are two places of so nearly the same name, or one which sounds so nearly similar, that it is difficult to distinguish them. The other one lies a mile and a half [illegible]ward of Katwâhi, and is spelled on the map Sôdhe.

c 2

		Feet.
6.—Carboniferous.	Compact carboniferous limestone	50
	Grey sandy marls, *Bellerophon*, &c.	3
	Thin-bedded grey limestone with marly intercalations ...	8
	Rusty dolomitic limestones	50
	Hard grey sandstone with *Fusulina*, *Spirifer* and *Productus spinosus*	6 to 10
	Thick, soft yellow sandstones, fossils in places numerous, *Fusulina*, *Productus*, &c.	25
	Reddish nodular sandstone	3
	Black coaly sandy shale	10 to 12
	Yellow sandstone with many fish-remains and *Spirifera*...	10
	Greenish sandy shales	6
	About ...	175
5.—Speckled sandstone.	Lavender clay with numerous irregular bands of grey marlstone changing downwards into	50
	Red sandstones with many alterations of red marl or earthy bands	50
		100
3.—Dark shaly zone.	Green sandstones and shales, in places numerous pebbles of metamorphic rocks	60 to 100
2.—Purple sandstone	... ...	200

Doubtfully two zones of hæmatite.

There appear to be (doubtfully) two hæmatitic bands in the country hereabouts, one above the carboniferous and another at the base of the nummulitic series, but both are rarely present together; and where fragments only of one of them are seen, it is difficult to refer them to their proper place; besides, the vertical distance between the two being small, one might be taken for the other.

Speckled sandstones.

The lavender clays of the speckled sandstone group are of irregular thickness, some sections showing them, as above, only 50 or even 30 feet thick, while others expose them with a depth of very much more than 100 feet. The sandstones of the same group are sometimes conglomeratic, sometimes not, and are generally much more developed than their representatives in the section

given above. The greenish sandstone and shaly zone No 3 appears to pass into the light-coloured top beds of the purple sandstone, and has lost all the characters which in its upper part to the eastward indicate the last extension of group No. 4.

In the carboniferous group, which has here assumed considerable proportions, the thickness of different very distinguishable zones varies much, the strong limestone bands of some places appearing of much greater thickness than in others. These strong bands are often cherty or crinoidal, and vary from thin-bedded or lumpy to thick solid limestone; the associated greenish, variegated, pale pink, coarse, or ferruginous sandstones are evidently inconstant both in place and character.

Slip.

A great mass of the nummulitic limestone has slipped down the cliff on the south-western side of this Katta hill, and on the spurs below the "purple" and "speckled" sandstone groups are seen divided by the shaly zone No. 3, a little of the red salt-marl appearing here and there below all in the smaller glens.

Coals.

Other slips occur in the deep limestone valley west of Arára, and among the debris lying heavily at the base of its enclosing cliffs. There are one or two small slipped exposures of the coaly shales below the nummulitic rocks; two thin coal seams occur in these. The group beneath the carboniferous does not run far up this glen, but holds on westward into the northern side of the Sangal Wán* greatly covered with debris and obscured by land-slips along the cliffs: all the larger local groups are, however, seen.

Sangal Wán valley.

In the Sangal Wán, west of Katta, there is evidence of both disturbance and dislocation. On its left side the purple sandstone and superior groups show themselves, but on the right, at its mouth, is a mass of white, splintery, compact carboniferous limestone, forming a horizontally bedded

* There seems to be rather a confusion of ideas as to where the Sangal (or Sungla) Wán really is. Its name is not marked upon the map, and the glen so called by natives of the country is not that west of Arára, but an east-and-west gorge nearly two miles north of Náli.

cliff 85 feet high. The beds soon begin to undulate, and some of the underlying speckled and red sandstones are placed by slips or faulting among the limestones. Further on along the north side of the Wán or glen, the lavender clay beds of the speckled sandstone group predominate, grey clays and ferruginous bands with white efflorescences appearing among them. At one spot the dark greenish shaly silurian zone is only 20 feet thick, the overlying "speckled sandstones" having an apparent thickness of only 40 or 50 feet. The hard sandy beds of the carboniferous group are seen in the little amphitheatre at the head of the glen, beneath lofty nummulitic limestone cliffs, the bedding of which rises rapidly towards the Kandawála peak, and the carboniferous rocks also cover the high ground between this and Náli. They are white, grey, thin and thick bedded limestone, with many strong beds of fossiliferous, drab, earthy and sandy calcareous rocks, separated by shale partings. The *Fusulinæ* here occur in grey compact limestone far down in the group, and also in more sandy beds at a still lower horizon. The "speckled sandstone" group below these limestones is more shaly than usual, earthy bands predominating in its upper part, and occurring again within 30 feet of its base. On the side of the hill over Náli this group (No. 5) has a thickness of 150 to 200 feet, and is surmounted by an escarpment-cliff of carboniferous limestone, much acted upon by the weather, as is shown by a poised fragment 15 feet in height, which has been gradually separated from the cliff by atmospheric waste.

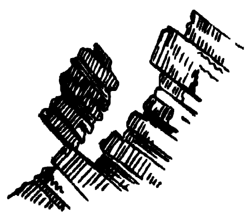


Fig 37.—Balanced mass on limestone cliff, Náli

LOOKING DOWN THE WARRÚ KUSS

Fig: 38.

The hill side, from the speckled sandstone outcrop downwards, is covered with debris in places, and where it is steeper, the rocks are found displaced, a dyke-like mass of the red marl being enclosed by parts of the purple sandstone on each side. Westward of this village of Náli much confusion prevails on account of this dislocation. A talus of debris conceals all the beds immediately below the nummulitic limestone, except a band of white friable sandstone 20 feet in thickness; while about 80 feet of decaying brown sandstone below this slope is probably the highest part of the carboniferous group. This latter group and the speckled sandstones beneath have here an estimated thickness of 300 feet each.

Náli

Not only are the rocks disturbed by slipping, but they are affected by a strong though local anticlinal curvature, the axis of which appears to coincide with a line of fault or other dislocation in the Warru Kuss, three miles west-by-south from Náli. At the north of this *kuss* or ravine the beds are much dislocated, and a narrow strip of the red marl contains in its upper part several beds of salt, dipping north-20°-west at 50°.

Warru Kuss

Salt.

The volcanic-looking, lavender, ashy clay of the Nilawán ravine, &c., re-appears here as a band of a few feet, just in the red marl beneath the purple sandstone group.

The salt is much exposed at some height in the banks of the ravine; it is of good quality, and some 114 feet in thickness; much of it occurs "at daylight," but the old mines have not been opened since the commencement of the English rule.

This Warru glen has been excavated, like the larger ones of Sardi and Nilawán, along the axis of the local anticlinal, and this nearly coincides with a line of slip or fault along the northern slope of the glen (see fig. 38, Pl. XXII).

Anticlinal and fault or slip.

The uppermost 50 to 80 feet of the purple sandstone is here quite light-coloured and massive, and a thin representative of the silurian shaly zone continues to

Series.

appear above it. The speckled sandstone group (No. 5) is conglomeratic, containing also earthy beds both above and below, and there is a regular transition upwards from its variegated and dark grey clays (here 130 feet thick), through 100 feet of black sandy shale, with hard muddy, thin, calcareous and cherty bands, into the limestones of the carboniferous group. At the head of the ravine this limestone forms a surface wild and broken by small cliffs, crags and escarpments. The nummulitic limestone generally rises above the carboniferous in long scarps with outlying portions here and there.

Country about Morah.

On the sides of these outliers towards the plains, masses of the carboniferous limestones still occur, shaken and slightly out of place. Between these masses the red sandstone group No. 5 is seen predominating towards the escarpment and supporting large slipped fragments and outliers of the limestone. Above the village of Morah in the broken limestone ground, the carboniferous limestones are often fossiliferous, the weathered state of the beds enabling numbers of *Rhynchonellæ*, small *Terebratulæ*, and other *Brachiopoda* to be collected, as well as many corals; certain white limestones being crowded with *Lithostrotion*.

Peculiar fossil.

Among the carboniferous fossils found here (and in other places also) there occurs a peculiar form with a large flattish palmate structure, having on one side a well-defined midrib, from which smaller deeply separated ribs diverge in opposite directions, sometimes at right angles, sometimes more obliquely placed. What this fossil is has not been discovered, but there is a similarity in some small curved specimens to internal casts of *Belerophon decipiens*, DeKonink.

A great boulder conglomerate of crystalline blocks occurs here just above the now greenish shales of the silurian zone, and bands of light grey sandstone occur in the lower part of the purple group No. 2.

Country eastward of Kánd Ghát.

Between Morah and the ghât (or ascent) on the road from Sháhpur to Sakesar, the escarpment of the hills is greatly broken. The speckled sandstones occur in force,

but the shaly zone No. 3 is very inconsiderable. The upper part of the carboniferous limestones are sandy, containing numbers of *Producti*, and there are fully 80 feet of sandy, calcareous, rusty and earthy beds overlying these and beneath the shaly base of the nummulitic series. A cliff of the carboniferous limestone measures 230 feet, although it includes only a part of the group, which may be altogether over 500 feet in thickness. The speckled sandstones are some 350 feet thick, and the purple sandstone group below, 300. The greenish shaly band between these two is scarcely 20 feet in thickness.

The salt-marl is seen at the foot of the hills, its relations being much confused by slipping of the next overlying beds; and in one deep ravine or *kuss* to the east of the Sakesar road it contains the hard dolomitic layers found with the gypsum at Khewra, and here studded with nests of iron pyrites.

Kúnd Ghât.

On the ascent from the plains to Katwáhi the "red marl," "purple sandstone," "speckled sandstone," carboniferous limestone, and nummulitic rocks are all seen. Land-slips have occurred, consequently some groups appear thicker than they really are. The section at this place over the crest of the pass and descending towards Sháhpur is as follows, taken from Dr. Waagen's observations and my own :—

Groups.		Ft.	In.
No. 11.	Nummulitic limestone (part of)	100	0
	Yellow nummulitic marls	15 to 20	0
	These change slowly into :—		
No. 10?	Brown marls with concretions and many fossils—*Beloptera* (?), *Nautilus*, *Gastropoda*, corals, and bivalves (cretaceous ?)	40	0
	Variegated ferruginous soft sandstone	30	0
	Variegated clay or shale and grey shales	40	0
	Band of limestone or hard marlstone with many fossils—*Orbitolites* (?) or *Nummulites* (?)	0	8
	Grey clays, with large spheroidal concretions like the Lias of Lyme Regis: calcspar veins	15	0
	Grey cavernous limestone, dark brown on fracture, filled with *Orbitolites* (?)	30	0
	Hæmatitic irregular band	15 to 20	0

		Ft.	In.
No. 6.	*Bellerophon* sandstone of the carboniferous upper beds, with *Terebratula*, *Producti*, Gastropods, tubes like *Dentalium*, and small fragmentary fish teeth	100	0
	Limestones chiefly	200	0
No. 5	Speckled sandstones and soft lavender and red clays, showing two slips downwards	300	0
No. 3.	Greenish shaly zone ...	35	0
No. 2.	Purple sandstones .	250	0
No. 1.	Red salt marl .	200 to 300	0

Alternation of lower purple sandstone and salt marl.

The red marl, in the glen opening on the road from the west, just where the ascent commences, alternates (unless the appearance is produced by slips) two or three times with dark purple bands of exactly the same character as the lower part of group No. 2. The rest of the groups succeed in their regular order, but on the south side of this glen a mass of the carboniferous limestone has slipped, or is faulted, so as to conceal everything else, and to be in contact with the red-marl group. About a mile and a quarter northwards of the pass are the hamlet and serai of Katwáhi, situated among hills of carboniferous and nummulitic limestone. Some of the ground about the village is either flat or cultivated, so as to cause difficulty in defining the boundary lines, one hill being of one limestone, and another of a different kind, with here and there small patches of red beds, belonging to the group No. 5 below the carboniferous, appearing in an obscure manner.

Katwáhi.

Coal shales.

Where the road to Sakesar ascends a hill from the immediate vicinity of the serai, some coaly gypseous shales which are exposed in the sides of the road-cutting, belong, most probably, to the nummulitic limestone which forms the adjacent hill. The two higher hills, one to the southward and the other east of the serai, are both of nummulitic limestone also, but between their beds and the underlying carboniferous rocks, some greenish shales and calcareous beds, containing a few *Ceratites*, make their appearance; these are some of the earliest traces to the eastward of a new (triassic) group which further west always accompanies the carboniferous rocks.

Ceratite beds.

The southern hill is part of a great outlying patch or basin of the nummulitic rocks around the escarpment of which the carboniferous limestones appear, the two together forming quite inaccessible cliffs some hundreds of feet high in a narrow gorge south of Sodhi (or Sothe) and south-west of Katwáhi. At the head of this gorge, where it leaves the flatter ground between nummulitic limestone hills, there are the remains of a tolerably thick bed of purple gypseous clay associated with sandstone layers and blackish shales. The gypsum or selenite is in clear plates, and the beds are probably a fragmentary portion of the upper part of the speckled sandstone group brought into this position by concealed faults.

Hills east of Katwáhi.

The hills to the eastward are partly formed of carboniferous limestone and partly of an extension of the main mass of the Sôn nummulitic limestone. At the base the latter is hard, grey, compact and lumpy, overlying 15 feet of white powdery sandstone. A small band of shales occurs below, and under these the hæmatitic clay bed which is often found near the base of this series. The layer is here 5 feet in thickness, but is always rather irregular, and in this neighbourhood sometimes entirely absent. Below the hæmatite are dark and light grey triassic shales, with some gypsum and ferruginous nodules and bands, the whole being 20 feet thick. Near these, and apparently coming from beneath them, is strong crinoidal limestone of the carboniferous group, weathering quite red, overlying a mass of the compact fossiliferous limestones of this group. In a little valley between two carboniferous limestone hills here, and leading down to the Katwáhi stream, close to the village, there is a green and red soft shaly band near the top of the speckled sandstones, without the usual quantity of lavender or other clays that usually intervene between these and the carboniferous group. Some 60 or 80 feet of these sandy and red clay beds of group No. 5 are visible, but are obscurely exposed. The rest of the hills in this neighbourhood form very rugged ground, and the limestone beds are frequently sharply contorted.

Khúra, Katwáhi.

Between Katwáhi and the village of Khúra (pronounced Khoora) to the north-north-east, there is a small flat plain entirely concealing the rocks, but the carboniferous limestones rise in abrupt cliffs on its north-west side. Close to the west of the village a section is seen of the junction between the triassic group and the nummulitic limestone. The rocks dip west of north at 40° and 20°, and the section is as follows* :—

		Feet.
No. 11.—Nummulitic.	Compact nummulitic limestone, *Alveolina* beds ...	10
	Precipice 50 to 60 feet high of compact nummulitic limestone	50
	Soft yellow marls, with *Nummulites* ...	60 to 80
	Brown marls, with many corals ...	15 to 20
	Soft yellow sandstones, with *Ostrea*	30
	White and yellow and red variegated soft sandstones, with plant fragments, partly covered by debris ...	20 (?)
	Olive calcareous sandstones, with *Conus*, small shell fragments, and lumpy nodules	30
	Strong ferruginous soft sandstones	40
No. 7.—Trias ...	Greenish and grey shales, variegated, red, yellow and blue at top; *Ceratites*	20 to 30
	Ceratite limestone	3 to 4
	Yellow sandy calcareous beds, with *Rhynchonellæ* ...	5
No. 6.—Carboniferous.	Brown dolomite, like that at Pail	3
	Grey and greenish calcareous and micaceous sandstone, with limestone bands, weathering red in parts and containing *Bellerophon*, *Productus*, &c.	90 to 100
	Compact carboniferous limestone very rich in fossils, *Strophalosia Morisiana*, *Productus*, *Athyris*, &c.	60 (?)
	Debris	
	Yellowish red sandstones and brown dolomitic limestones like those at Pail	
	Gap	
No. 5 ...	Lavender clay appearing	

It is possible that some of the beds above included in the nummulitic group may be cretaceous; *Conus* is found to the eastward in other rocks, believed to be of this age; but these, for want of sufficient evidence, are not separated here as a different group.

* From Dr. Waagen's and my own observations.

Eastward of Khúra the nummulitic limestones soon close in round the end of the small plain. Northwards, they undulate, and at one place on the road to Sodhi are not only bent into a sharp curve, but also faulted, some of their underlying shaly beds appearing in the side of the road at the steep descent leading to the Sodhi valley and bungalow.

Nummulitic east of Khúra and to the north.

The post-tertiary deposits of the upper part of this Sodhi valley have been already alluded to; they are well seen near the junction of the road from Khúra with the Sodhi and Sakesar road; where drab clay and coarse brown, soft, sandstone, with limestone pebbles, lying on the south slope of a nummulitic limestone hill, dip at so high an angle as 20° to south-by-west, and are unconformable to everything below. The same beds occur again in the country near Naoshera.

Post-tertiary conglomerate.

Naoshera.

Westwards from Khúra the upper carboniferous beds and overlying trias continue along the indented boundary of the nummulitic rocks, a long narrow promontory of which juts out to the east-by-south for about four miles from their main mass; small outlying patches also occur. The direction of this extension of the newer limestone is almost exactly parallel to a large fault running from near Katwáhi to the westward, and bringing the carboniferous, the nummulitic, and tertiary sandstone groups into abnormal junction.

West of Khúra.

From this fault another is supposed to start in a south-westerly direction through some undulating or flat ground till it reaches the Kávhád gorge, down which it passes out towards the southern plains. In the flat ground, of course, this fault is concealed, but nearer to the gorge nummulitic and carboniferous rocks are brought against everything lower than the latter. To the right of this Kávhád ravine the ground is hilly and covered with broken masses of carboniferous limestone and the "purple sandstone" is seen overlying a large exposure of the salt-marl. On the left-hand side

Kávhád.

of the stream the carboniferous beds, slipped and faulted here and there, form abrupt ground several hundred feet higher than the bottom of the glen and are covered by the nummulitic limestone. Further down the stream, some of the speckled sandstone beds crop out on its left bank beneath the "carboniferous beds," while on the opposite side of the stream these carboniferous limestones are in junction with the "red marl." The latter ends suddenly, and for some distance the bed of the river is in the speckled sandstones, which, with the underlying purple group No. 2, diverge to the southward along a slip or fault, and again the carboniferous beds of the left bank are in discordant junction with "red marl," "purple sandstone," and "speckled sandstones," while carboniferous limestones form the most of the right bank and steep hill side above it. These groups continue in a most shattered state nearly to the mouth of the gorge, where the stream bends to the south and the fault continues onwards up the right bank.

The sketch (fig. 39, Pl. XXII) will convey an idea of the lower part of this glen, through which it is not often easy to trace the geological boundary lines. The ground to the right of the view is almost all of carboniferous rocks much displaced, that to the left above is of the same, while below are the "speckled" and "purple sandstones" and the "red marl" in a most confused state. Old Sikh salt-mines were worked in this glen, and some of the compact thinly laminated, dolomitic layers, observed elsewhere, recur here in the red marl.

Between Kúnd ghát and Kávhád glen.

The escarpment country along the southern face of the hills, between the Kávhád ravine and the road from Sháhpur to Katwáhi, is extremely disturbed, numbers of slips having taken place, and the rocks having given way generally along rough contours of the ground. Great sheets and scarps of the bare carboniferous limestone, thrown into curves and basins with various dips, form bold cliffs rising above the broken ground, and lower terraces are also covered with decomposing masses of the same rocks displaced; while the deeper glens and under-cliffs show various complicated arrangements of the "red salt-marl" and the two overlying sandstone

groups. The slips and alternations of the rocks are too confused for close description; much of the ground is covered by debris chiefly of the carboniferous group, projecting from beneath which, isolated portions of any of the local rocks may be found.

There is here very commonly a zone of sandy, olive, micaceous beds 50 feet or so in thickness at the base of the carboniferous formation, and the strong limestones above may be estimated at 500 feet at least, if not more,—the repeated step-cliffs making its depth appear much larger than it really is. The lavender and grey clays again form a thick band at the top of the "speckled sandstone" group; they are gypseous, and in places contain light olive, micaceous sandstone layers, ferruginous beds, and layers of black and grey shale. The thickness of this portion of the group varies from 50 to more than 100 feet, and the underlying red, white, and speckled sandstones and clays are from 250 to 300 feet. Between these and the purple sandstones below there is still sometimes an eight-feet greenish shaly zone on the silurian horizon; and in the red marl beneath, thin purple sandstone and grey gypseous and cherty-looking dolomitic flaggy layers occur.

Jabi spur.

Great masses of white clay occur in the debris on the end of the Jabi spur above the left side of the Dokri gorge. Some disintegrating nummulitic limestone near the place suggests that the clay may result from the decay and re-arrangement of its lower marly beds, but the local debris conceals the relations.

Ammonite or *Phylloceras*.—(Waagen.)

About a mile north of Jabi, portions of the carboniferous rocks, slipped, fallen, and displaced, still retain sufficient continuity of relation to enable their former place in this series to be recognised. In a broken-down mass, belonging to the lower part of the upper beds of this carboniferous formation, Dr. Waagen found the oldest known *Ammonite*, or, as he has since determined it, *Phylloceras*; which unique and interesting fossil forms the subject of a short paper in the Geological Survey Memoirs, Vol. IX, p. 351. It was associated in the limestone with the following: *Athyris Roysii*, *Productus costatus*,

P. spinosus, *P. cora*, *P. Humboldti*, a *Retzia* described by Davidson, *Terebratula Himalayensis*, *Fenestella*, *Macrocheilus*, *Goniatites*, *Ceratites*, and many other carboniferous forms.

Carboniferous rocks north-west of Kávhád and Dokri gorge.

From the mouth of the Dokri gorge a steep path near a salt chowki leads up the cliffs on the right side of the glen to the undulating plateau above. From this path the broken and dislocated positions of the several groups can be seen. Where the rocks begin to appear *in situ* at the cliffs of the escarpment, greenish and thinly laminated flags occur in the upper part of group No. 5, and the white and red variegated clays of that horizon are sometimes hard and jaspery, the beds with the harder layers being 50 feet thick. Over them are 55 feet of grey calcareous sandstone with a one-foot fossiliferous band containing *Spirifera*, *Producti*, small *Bellerophon*, *Terebratulæ*, &c. Succeeding to this band are 10 feet of greenish clay, overlaid by 12 feet of sandy limestone, weathering brownish, with *Fusulinæ*. This limestone is overlaid by 30 feet of greenish micaceous clay, then 150 to 200 feet of solid limestone with corals, passing upwards into 120 feet of brown, rusty, thin-bedded *Bellerophon* limestone, forming the cliff-edge. Other rusty calcareous beds succeed and undulate over the neighbouring hilly plateau, the nearest prominent elevation of which is capped by the whitish-yellow disintegrating lower beds of the nummulitic series.

Plateau.

Viewed from one of these heights, the plateau appears like a grey limestone sea thrown into huge waves, some turning over as if about to break, and the slopes of all "dressed," or rendered smooth, with detritus. Among all these grey rocks the whiter debris of the nummulitic limestone can be occasionally detected, and some smoother greenish slopes show where the soft triassic strata may be found.

Between Jalár and Kávhád.

To the north-eastward the country between the Kávhád gorge and Jalár Kahár is most peculiar. It is, as usual, hilly and covered with the detritus and masses of the carboniferous limestone in such a state that it is almost impossible to

say which ground is formed of rock *in situ*, and which merely of debris; in fact one form so closely resembles the other that no hard line of demarcation exists. Over this ground are scattered patches of the nummulitic limestone which have to a great extent undergone degradation and yet retain much the appearance of being *in situ*. One tract north-west of Sothi is covered by the triassic beds, generally much broken, but in places actually *in situ* resting on the upper beds of the carboniferous limestone; while some of the hills and all the deeper valleys show the "speckled sandstone" exposed by denudation. Near Gogra the underlying "purple sandstone" appears with patches of the "red gypseous marl," all in a very confused condition, the nearest rock to the marl being sometimes its proper associate, the purple sandstone, but sometimes the nummulitic limestone or one of the other groups. This confused and much disintegrated ground extends north-westward in and along the valley of a stream which runs from near Nanga west of Jalár into the larger gorge near Kávhád. Towards the upper part of the stream, and between it and Nanga, nummulitic limestone in an almost detrital state prevails; but the red sandstones, &c., of group No. 5 are seen in the stream bed.

Jalár.

In the neighbourhood of the village and so-called fresh-water lake (which is, however, saline) of Jalár, the carboniferous limestone forms hilly ground to the south, and cliffs to the northward, of a little plain, which ends at a complicated and deep clay *khuddera* to the eastward. There seems to be an east-and-west fault passing along the foot of the northern limestone cliffs, and exposing some of the underlying speckled and reddish sandstones here and there. To the north of these cliffs and rising obliquely on the northerly slope of their beds, a narrow (triassic) Ceratite band is occasionally seen, succeeded by the nummulitic limestone. The whole of the latter is present, dipping also northwards at 55° and overlaid by a long narrow basin of the lower tertiary, bone-bearing, greenish sandstones, etc., with a few red clay bands. These sandstones,

Trias.

Tertiary sandstones, &c.

some 200 feet in thickness, are very soft and friable, and consequently occupy the bottom of a valley. The basin is incomplete, being faulted in an east-and-westerly direction against a narrow strip of the *Bellerophon* beds of the carboniferous limestone, which forms an escarpment overlaid by the triassic and nummulitic beds.

This locality was visited by Dr. Waagen, whose notes on the detailed section are given below :—

		Feet.
NUMMULITIC ...	Compact nummulitic limestone	
	Yellow marls with *Nummulites*	30 to 50
	Brown marly layers with a few traces of corals ...	
	Grey and yellowish clays with concretions and *Valsella*-like bivalves	20 to 30
TRIAS ...	Hæmatite	6 to 10
	Hard limestones with Bivalves	4 to 5
	Thin-bedded hard limestone with different species of *Ceratites*	10
	Brown sandstone with *Ceratites Flemingi* ...	10
	Brownish and light yellow sandstone with few *Ceratites*. In the upper part of these sandstones is the *Bellerophon* bed of this Ceratite group	80
CARBONIFEROUS.	Ceratite marls and hard thin Ceratite limestones ...	20
	Brown sandstones and sandy limestones of the *Bellerophon* group, very thick ...	100 to 150

Northwards from this the nummulitic limestones undulate with a good deal of northerly dip into the Sôn Sakesar Kahár basin. To the eastward they are more violently contorted, and in the hills behind Naoshera they are covered by unconformable detrital beds (similar to those of the head of the Sodhi valley) dipping northwards at low angles generally of about 10°.

Jurassic.

Westwards of Jalár the carboniferous limestone cliffs which overhang the lake extend for several miles, and are more palpably faulted along their base. The limestone is overlaid by the Ceratite zone, and this by a new group of white, red, and yellowish soft sandy and variegated beds, the commence-

ment of the jurassic group. Here in their first exposures the jurassic beds are thin, faulted, and much concealed. South of Nanga (to the west of Jalár lake) there is a considerable hill (beyond the broken belt of disintegrating nummulitic limestone) at the base of which carboniferous limestone appears; and further up the triassic Ceratite band, overlaid by a few sandy beds representing the jurassic rocks, and capped by nummulitic limestone with a southerly dip.

These beds are cut off by a west-north-west fault bringing them against the carboniferous limestone, here forming a wide hilly tract, its beds dipping both to the north-east and south-west, and its chief lines of hill and valley trending west-north-west.

Virgál.

South-westward of this tract, and westward from Virgál, is a narrow elongated basin formed by a synclinal curve in the carboniferous limestones, but occupying high ground. Within it, the triassic beds, a few jurassic layers, and an outlier of the nummulitic limestone, lie, each surrounded by its adjacent lower group, their outcrops forming escarpments on the north-eastern side and south-eastern end of the basin, but being overtopped by higher limestone hills in other directions. The north-east side of the outlier presents the following succession according to Dr. Waagen :—

		Feet.
NUMMULITIC ...	Compact nummulitic limestone, over yellow nummulitic marlstone ...	20
	Gray clays with very much gypsum, hard concretions with fossils ...	12
	Hæmatite ...	4
JURASSIC ...	Variegated sands and sandstones ...	10
	Brown sandy marls with *Turritella* ...	5 to 6
	Soft red sandstone with greyish and greenish clays, pyritous and gypseous ...	15 to 20
TRIAS ...	Grey limestone with numerous Bivalves ...	2
	Thin-bedded hard sandy limestone, no fossils ...	6
	Ceratite sandstone, thin-bedded soft yellow sandstone with gypsum; a *Bellerophon* bed in the upper region ...	50
	Green Ceratite marls ...	60 to 70
	Thin-bedded limestone with *Ceratites* ...	8

		Feet.
CARBONIFEROUS...	Grey sandstone layers	6
	Black coaly, shaly beds, micaceous...	3 to 6
	Thick light grey concretionary sandstones with nests of fossils, small *Producti*, *Bellerophon*, and *Gastropoda* ...	6
	Brown sandstone and limestone with *Bellerophon*, *Productus costatus*, and a *Dentalium*	200 (?)
	Compact limestone with corals	300

I found some of the *Ceratites* in the shaly beds on the south-west side of the basin to be of large size, occasionally measuring thirteen inches across. At this side of the basin there are also seen some 30 feet of white sandstones above the hæmatite zone, succeeded by 20 to 30 feet of dark-coloured shales beneath the yellow marly beds of the nummulitic limestone. At another place the hæmatite band measures 15 feet and is overlaid by 25 feet of white sandy beds, both being displaced; and at the south-eastern end of the basin an old pit was shown to me in what appeared to be a dislocated fragment of the hæmatite: from this pit-alum shale was reported to have been raised. Alum workings are not, however, now carried on here.

The grey limestone with numerous bivalves, marked as 2 feet thick in the above table, is nearly 10 feet on the opposite side of the trough, and the shaly beds are covered with saline efflorescence.

The high hill south-west of this (3,408 feet) is scarped towards the basin and formed of the hard fossiliferous (carboniferous) limestone, folded so as to add much to its apparent thickness, which would be great even if undisturbed. The limestone of the carboniferous formation is frequently dolomitic in this neighbourhood, in the lower country along the escarpment of the range. In the neighbourhood of Choya (Chúa) more than the usual amount of disturbance and dislocation prevails.

Choya.

On the right side of the Dokri gorge, within a mile from its mouth, there are four large and many minor ground slips, one of which is probably along a continuation of the Kávhád fault. Further west the entanglement of

Dokri.

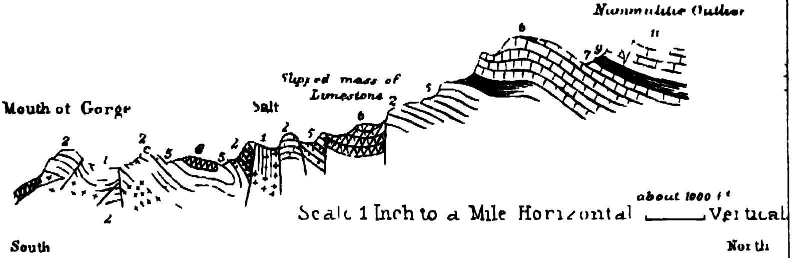


Fig 40 Section on right side of Choya gorge and up to Triassic & Nummulitic outlier

1 Salt marl Purple sandstone 5 Speckled sandstone 6 Carboniferous limestone 7 Triassic shales 9 Jurassic sandstone 11 Nummulitic limestone

Fig 43 Greenish band in Red marl Vurcha Glen

a Gypseous veins in dark greenish grey clay b Purple and greenish flaggy shale c Red marl

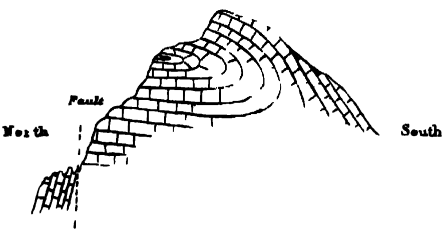


Fig 44 Top of Kangarawala Hill

the rocks from the same cause becomes intensely complicated. The succession is the same, but the "purple sandstone" is much less seen, except in the cliffs nearest to the main escarpment, where it still retains its thickness of about 250 or 300 feet. Even here there is occasionally a thin, greenish, shaly, micaceous band, between it and the "speckled sandstone," the thickness of which last appears much to exceed that of the former groups. Along the foot of the hills the "red marl" and the "purple sandstone" are frequently but not well exposed underneath the debris.

Choya gorge.

In the Choya gorge many singular complications occur, the lower rocks of the overlying series having slipped downwards over the salt-marl, sometimes producing the appearance of alternation, whilst sometimes nearly isolated masses from above have reached the bottom of the glen. The "red-salt marl" is much exposed, and crops out on the shoulder of the spur between the gorge and the village of Choya, at a considerable elevation above the latter. The water is all salt with the exception of a small driblet, issuing at the left side of the mouth of the gorge from the gypseous red marl; a hollow which might hold a pint having been formed to receive the supply around this, a cluster of the village children stood waiting their turn to obtain a tardy lotahful, warm and not particularly good when gained. The "red marl" has a more stratified appearance than usual owing to the prevalence of gypsum, the layers dipping at high angles on account of much disturbance of the rocks (see fig. 40, Pl. XXIII).

Salt-marl.

Dolomitic flags and shaly layers in marl.

At some distance within this glen, bands of the grey cherty-looking dolomite and grey (weathering greenish) clays or shales with ferruginous strings, occur quite vertically bedded in the salt-marl, the flaggy dolomite bands alternating frequently with dark brownish grey thin shales. At one place these beds measure 50 feet, and present in their regular stratification a strong contrast to the adjacent marl.

Slip fault.

Further on, the stream runs through the sandstones, &c., of group No. 5, and between masses of the carboniferous limestone, that on the right side of the stream being displaced, shaken, and brought against the "purple sandstones" by a fault along which the lavender clays of the group (No. 5) are crushed into contact with the lower purple sandstone beds.

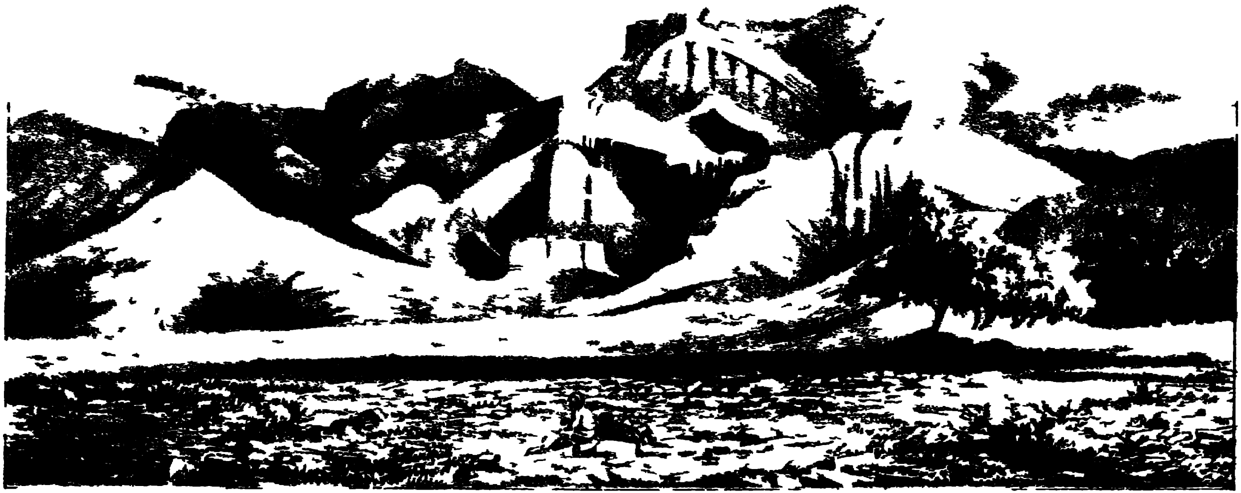
Head of Choya glen and ascent to the north.

The stratification of the rocks at the head of this glen is well seen, the "purple" and "speckled" sandstone groups dipping at 50° to the northward and rising into a high hill overtopping the plateau country. The northern slopes of this hill are on the dip of the bare rocks, lessening with the descent, until nearly at the foot they pass beneath an outlying patch of the carboniferous limestone, partly horizontal and partly taking the opposite inclination of a synclinal curvature. Two or three streams meet here; following the most northerly over rough ascending ground, the "purple sandstone" and overlying groups are passed, and a curious narrow, deep, winding cut, which can be touched at once on either side, leads through the carboniferous limestone cliffs, up over a "bad step" and into the basin occupied by the triassic and overlying groups of the Choya section (fig. 40, Pl. XXIII). Immediately over the village of Choya, much "red marl" and several hetereogenous, fragmentary patches of the other groups are exposed.

Gorge between Choya and Varcha.

To the westward in the gorge between the village of Choya and Varcha (often called Wurcha) the red salt-marl is again largely exposed; here it contains salt and produces a white efflorescence from saline portions called by the natives *túr*. It is much cut up by slips, but there appears to be an 80-feet band of purple marl and thin sandstone below the uppermost 30 feet of the red marl; the gypsum in this causes it to retain some traces of stratification in the neighbourhood. The lower 60 feet of the overlying purple sandstone group is unusually argillaceous, and this appearance of an alternation between an upper band of the red marl and the lower portion of the purple sandstone is also seen in a few other places in the vicinity.

Wynt Selt an



1 4 Red Ma near archa

Varcha village.

Just in the neighbourhood of Varcha (Wurcha) the rocks are again tremendously broken and slipped, great shifted disintegrating masses of the carboniferous limestone directly overlying the red marl, and portions of the other rocks being entangled with this marl, at many points, without any of their consecutive relationship being preserved. The shaken and displaced limestone overlying the salt-marl can be continuously traced into connexion with that which is still *in situ*, horizontally undulating over the higher ground, the transition from one condition to the other being imperceptible. Open fissures and chasms, of great depth but inconsiderable width, occurring in the limestone are probably due to the instability of the underlying salt marl.

Between Varcha village and gorge.

Between the village of Varcha and the Varcha gorge to the northwards the "red salt-marl" is seen, forming a part of the Varcha exposure of the Saline group, one of the largest in the western part of the range.

The red marl here is conspicuous from the plain at the foot of the escarpment, and fills a small rugged valley. Gypseous interstratifications occur, and parts of the formation appear in many places to have subsided. The marl lies very high, entirely forming hills, which measured by aneroid 740 feet in height above the plains (see fig. 41, Plate XXIV).

Crossing these hills into the Varcha gorge the same marked appearance of interstratification at its junction with the purple beds above, was again observed, there being more than one alternation of bands each about 50 feet in thickness.

The ground in this neighbourhood is, however, greatly dislocated, so that some doubt attaches to the occurrence of alternations; an appearance which might very easily be caused by subsidence along concealed lines of slippage.

Varcha gorge.

Within the Varcha gorge itself there is again much disturbance and dislocation; portions of the purple sandstone are so slipped or faulted on the left-hand side of the gorge

as to be entirely included in the marl, giving with the doubtful interstratification mentioned the appearance of at least three alternations of "red marl" with the lower beds of the "purple sandstone."* Besides this, masses of the "speckled sandstone" group have subsided between portions of the latter rocks, which appear much thinner than usual, and both at the mines and towards the head of the gorge, complicated landslips cause the carboniferous limestone to rest on the "salt-marl," with only the intervention of the upper lavender clays of the "speckled sandstone" group. At one place on the right side of the gorge, northwards from the mines, there are some greenish sandy beds intercalated between the "purple" and "speckled" sandstones in the place of group No. 3, which as a continuous band disappears far to the eastward about Khúnd Ghât on the road to Sakesar from Sháhpur.

Alternation at upper part of salt-marl.

Greenish sandy beds.

Above the speckled sandstone and its lavender clays, the carboniferous limestone appears everywhere on the heights surrounding the glen. Near its mouth, faulted or slipped and disintegrating masses of the same rock in immediate junction with the salt-marl form the low outer hills.

Carboniferous.

The thickness of the purple sandstone may be partly concealed by slips here, but at the head of the glen it seems to have diminished to 150 or 200 feet. The speckled sandstone group is also apparently thinner, the sandstones being from 100 to 150 feet, and the clays above from 50 to 80 feet, or for the whole group from 130 to 250 feet. The thickness of the carboniferous limestone, from its manner of exposure making differently sized cliffs in different places, is not very easy to estimate, but the hard cliff limestone may be about 250 feet or less, having some 50 feet of sandstone beds below, and 80 to 100 feet of other sandy calcareous beds with *Bellerophon*, &c., above, making the whole group 350 to 400 feet.

* These appearances, at one place on this left side of the glen, certainly have very much the aspect of natural and successive alternation.

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SHAFT VARCHA MINE

Varcha salt mines.

The Varcha salt mines are situated on the right side of the gorge, not far from its mouth, the entrance to the mines having been excavated through the lavender clays at the top of the speckled sandstone group. For 100 feet into the mine these beds and purple clays, or marls, are passed through, too irregularly stratified to afford much information, but the general dip is to the west at 30°. Within, the mine is worked in the usual salt and salt-marl: it is a very extensive excavation which follows a 20-feet bed of salt dipping at 20° to west-20°-north, and also to the north-west, the angle growing steeper as the salt bed descends. The general strike is from east-north-east to north-east, and the length of the mine is some 450 feet. The salt is of the usual reddish white colour. In one part of the mine old workings exist, without pillars, to support the roofs of the large and dangerous chambers left by the old miners. At the north-eastern end of the mine is the old Sikh entrance, and near it are some large vertical natural shafts with curiously fluted or moulded sides, showing the great thickness of the salt. (See fig. 42, plate XXV.)

Salt is also known in other places in the glen, but on its left side, just opposite to the mines, the salt bed (if present) is concealed, probably by land-slips.

Flaggy beds in red marl.

At some distance up the gorge beyond the mines, the flaggy and shaly, grey gypseous and dolomitic bands occasionally met with in the red marl, appear more frequently than is usual, and at one spot, though contorted and slipped, close on the bank of the stream, they have the following arrangement (see fig. 43, plate XXIII) :—

Variegated purple clays	10 feet.
Gypseous layer	1 „
Purple and green and grey clay	5 „
Strong rugged bands of white gypsum	4 „
Greenish grey clay shale, black where wet, weathering whitish	5 „ 2 inches. (? 10 feet if not slipped.)

Hard dolomitic flaggy bands alternating with thin grey shales, having yellow partings	...	3 to 5 feet.
Dark grey gypseous shale	... ...	5
Red marl again underneath	... ...	(?)

Still further up the glen a similar group of beds is again seen with a 25-feet band of salt immediately above the upper purple portion of the saline marl; the same kind of greenish beds, but without the salt, reappear where a stream from the east enters the main channel. As there is a large quantity of the salt-marl exposed here, and these thin-bedded bands are generally seen in the lowest situations, it might be inferred that they occupy a low horizon in the group, but their association in this place with rock salt, which is usually found near the top of the marl, and the possibility of slips having taken place, render the relation of the flaggy layers a matter of doubt.

Upper glen.

The large glen of Varcha is separated from an upper and smaller one by a cliff of the carboniferous limestone, which must have subsided considerably, for the underlying speckled sandstones are slightly visible, forming the floor of the upper valley. On both sides of the smaller glen the carboniferous beds are fossiliferous, containing, with other forms, some fine specimens of a large *Streptorhynchus*. In the upper part of this glen, where crossed by the road to Uchâli (hardly passable), the greenish trias beds occur in a synclinal of the carboniferous rocks, the latter being much folded about this part of the Sôn plateau.

Trias.

Between Varcha and Âmb.

Between the mouth of the Varcha glen and that of the Âmb valley there is another large oval exposure of the "salt marl," the "purple" and the "speckled" sandstone, and the carboniferous groups, evidently much dislocated and not in consecutive order. At the north-western side of this exposure there is again the appearance of some of the red marl overlying a lower portion of the purple sandstones, but the country is so slipped that appearances cannot be trusted. Between these two glens the red marl is very generally traceable along the base of the hills.

North-west of Varcha is the extensive, wild, and beautifully situated glen of Ámb. The main glen runs from the low plains in a curving north-easterly direction up to the southern foot of Sakesar mountain. It is a deep rocky gorge buried among lofty hills and joined at different points by three other valleys from the south-eastward. In this glen, its sides and its branches, the whole of the Western Salt Range series is to be found; but so intense is the dislocation from which the rocks have suffered, that in no place is a regular unbroken section observable. In addition to the difficulties caused by faults and very numerous landslips, violent contortion has in places affected the rocks.

Ámb glen.

The "red marl" is seen in many places in the main gorge, and in that branch in which Ámb village is situated; but only one place was indicated by the natives, at about half-way up the main glen, where salt is said to occur, and there are no mines open.

Series.

The "purple sandstone" is capriciously distributed; there is a good deal of it seen about the mouth of the glen, and immediately within the gorge, but further up it is either absent or very thin in comparison with its usual development. In the gorge, too, just above this group, are some greenish shaly beds in the place of group No. 3, but only locally present.

The "speckled sandstone" group is largely present, having an assumed thickness of 300 feet, and showing some slight local changes of character, the lavender clays still forming its upper zone. The carboniferous limestones are sometimes magnesian, and are often intercalated with sandstone beds and even in places with coaly shale bands; and in these limestones the most remarkable contortions in the glen occur. The triassic beds appear either in isolated faulted exposures, or in their proper place in the series, on the southern side of Sakesar, where the overlying jurassic rocks are also exposed. The nummulitic limestone surrounds the head of this main glen, and stretches along its

northern side, forming the higher part of Sakesar mountain. Far to the south, in one of the small tributary valleys to the left of the gorge, an isolated, faulted, and subsided fragment of these rocks occurs, associated with some of the coal-shales beneath, and in junction with a remnant of the overlying petroleum-bearing tertiary sandstones, the manner of their exposure being singular, and the connexion between their present position and their original mode of occurrence not easy to trace.

Faults.

Of many faults in the glen the principal one runs down the left bank of the main stream, crossing it north of Ámb, and obliquely ascending the opposite side of the glen. This fault appears to be a continuation of that at Jalár. Another runs up the branch glen beneath Ámb village, and there are others besides. Two or three principal lines of land-slippage coincide with the general run of the main glen, former cliffs having slipped down the south face of the Sakesar mountain; while nearer the mouth of the glen, the number of these dislocations and the variety of their directions give the whole mass of the rocks a most confused arrangement.

Hill east of gorge mouth.

The hill to the east of the mouth of the gorge is capped by the carboniferous limestone, undulating or dipping northward. This limestone is surrounded by its own debris, below which the "speckled sandstone," "purple sandstone," and "red marl" groups appear. Towards the gorge the two latter alternate along nearly north and south lines of slippage, none of the groups being entirely exposed. On the opposite side of the glen's mouth, gently rising ground is covered with limestone fragments, but further up portions of the speckled sandstone and carboniferous limestone appear, none of which, perhaps, are in their proper situations. High up on this ground a narrow shifted band of the salt-marl crosses out from Ámb glen, and runs along to the west, partly occupying high ground and partly the first depression behind the outer hills. It is associated with numerous

West of mouth of glen.

broken portions of the speckled and reddish sandstone or carboni-ferous groups, one little triangle being occupied by triassic beds.

Within mouth of gorge.

Just within the mouth of the gorge the crushed and broken rocks exhibit some most complicated folding, and the beds above the "purple sandstone" differ somewhat from the usual aspect of the "speckled sandstone" group; the following succession being observed:—

Groups.		Feet.
No. 5.	Bright red aluminous beds	30
	Greenish, greyish, and white flaggy sandstones and sandy shale with some red bands	100 (?)
	Hard white sandstone and grey shales	30
No. 3?.	Greenish grey, sandy, shaly, soft beds	50
No. 2.	Dull purple sandstone	80 to 100
	Purple shaly and earthy part of the group ..	60 to 80
No. 1.	Red salt-marl	80

This is on the west side of the gorge. A little further on, an isolated block of the carboniferous limestone, 40 feet in width, projects from the red salt-marl. Near this place, where the bottom of the gorge is occupied by the red marl, the purple sandstone forms the lower part of the right bank, and a slipped or faulted portion of the same occurs on the left, running in between masses of the carboniferous beds, which in this part of the gorge almost everywhere form its left side.

The second stream of any size above the mouth of the gorge on this side, enters the main one from a little valley, the south-west side of which is formed of the carboniferous limestone, dipping north-east at 45° and 50°, and the opposite side chiefly of limestone debris. About three-quarters of a mile up this smaller valley is the Salgi coal locality.*

Salgi coal locality.

* Described at page 15 of Dr. Oldham's "Memorandum on the results of a cursory examination of the Salt Range, &c.," previously referred to.

Here the isolated mass of the nummulitic limestone, before mentioned, occurs on the right bank of the stream for about 100 yards. At the north-western end it is in contact with some of the greenish triassic shales, the limestone being overlaid (instead of underlaid as might have been expected) by a 4-feet bed of white sandstone, succeeded by a conglomerate of possibly recomposed nummulitic limestone pebbles. Resting upon this are a few beds of tertiary sandstone of two kinds, purple, and grey pseudo-conglomeratic, coarse, soft, or speckled sandstone. The coal-shales beneath the nummulitic limestone are greatly crushed, the coal being very bad, rather a highly carbonaceous shale with a few plant fragments, and the most coaly portion varying from 3 inches to a foot in thickness. Beneath these shales Dr. Oldham seems to have observed some of the salt-marl, which may probably have been subsequently concealed by the stream deposits. It occurs, however, a little way north-east of the nummulitic limestone, away from the stream. A few yards further up the course of this, some more beds of the tertiary sandstones come in over the limestone, the section being as follows, and the beds dipping east-north-east at 30° :—

		Feet.
TERTIARY SANDSTONE.	5. Red clay.	
	4. Grey soft sandstone	30
	3. Brown sandstone	10
	2. Grey sandstone...	35
NUMMULITIC (?)	1. Limestone conglomerate	21
	(An original rock or recomposed from debris ?)*	

From the brown sandstone, No. 3, a small quantity of mineral tar was oozing out and running down the bank for 15 feet. The rock is very tough and strongly impregnated with the petroleum or tar, which burns with a red flame, sputtering much, doubtless in consequence of the presence of water. Beyond this the carboniferous limestone forms both sides of the valley, but to the north-east of the coal and tar locality, within a mile, denudation and dislocation have exposed some of the "speckled sandstone"

Mineral tar.

* This conglomerate may perhaps represent the similarly placed detrital junction-rock at the top of the nummulitic limestone of the East Salt Range, on the hills south of Phadiál. See p. 103.

beds and the "red marl" beneath. Returning to the main gorge, the lower portion of it still exposes the red salt-marl, rising considerably above the bed of the stream, the occurrence of salt being indicated by a *chowki*. Here the path to Ámb leaves the bottom of the glen and ascends a steep hill of limestone (the ascent having given a barometric depression of ·6 of an inch by aneroid); after which a slight descent leads into the smaller valley within which that village is situated. The fault which longitudinally traverses this smaller valley branches in the neighbourhood of the village so as to include a wedge-shaped mass of the "speckled sandstone" group, having on one side the "red marl" upon which the village stands, and on the other a portion of a basin of the jurassic, triassic, and carboniferous rocks. The red marl is gypseous and stratified, dipping towards the north-east at 40° to 50°, and just above it only the lower or shaly portion of the "purple sandstone" is represented. The succession of the beds at the village is as follows:—

Ámb village.

		Feet.
6 CARBONIFEROUS	Carboniferous limestone.	
5. SPECKLED SANDSTONE ...	Grey clays, yellow partings	40 (?)
	White sandstones, weathering greenish	79
	Greenish shaly layers and conglomerates of metamorphic pebbles	50 (?)
2 PURPLE SANDSTONE ...	Grey lumpy, sandy, shale	1·5
	Dark purple and greenish clay ...	80 to 100
	Purple flaggy shale	100
1. SALT-MARL ...	Compact white gypsum	25
	Grey and red shaly marl	4
	Red salt-marl, gypsum veins	70

The representatives of the "purple" and "speckled" sandstones (No. 2 and No. 5) extend up the valley in an east-south-east direction, until they disappear beneath the carboniferous limestone. A fractured segment of a basin containing newer rocks than these lies below Ámb, along the stream on the northern side of which the village stands. From the heights above the village the carboniferous limestones may be seen on the opposite hill-side dipping in northerly directions, and passing beneath the newer and softer beds along the course of the stream.

Change in the Purple Sandstone group.

Section inside valley below village.

The instructive section which this valley affords is as follows (according to my notes and those subsequently made by Dr. Waagen):—

		Feet.
11. NUMMULITIC	Nummulitic alum-shales with few fossils (same as at Chichâli pass, Trans-Indus) *Turritella, Trochus* and little corals.	
	White soft sandstone with numerous fragments of lignite	6
JURASSIC (?) ...	Alum-shales thicker than above and with more pyrites	50
9. JURASSIC ...	Strong red ferruginous sandstone with *Ostrea, Exogyra*, some indistinct Gastropods and fragments of unsymmetrical *Echinidæ*; section not quite clear, and part seems as if some grey sandstones came in above these ferruginous ones. Grey and variegated sandstones and shales, coarse yellowish flaggy sandstone with numerous *Terebratulæ*	50
	Variegated red shales ... ... Thick white sandstones ... . Variegated shales, blackish, grey and red	100 to 150
7. TRIASSIC ...	Hard limestones, numerous species of bivalves, calcareous sandstone with spinose *Ceratites*, sandstones with *C. Flemingii*, *Bellerophon* bed of the Ceratite group with many *Ceratites*... ... ... Ceratite marls, grey and green ... ... Lower Ceratite limestone	160
6. CARBONIFEROUS	Soft white sandstones intercalated with coaly shales, fossils numerous, *Bellerophon*, small bivalves, &c....	100
	Compact carboniferous limestone	200
	Yellow dolomitic sandy limestones	150 to 200
	Grey sandy brittle layers with numerous *Strophalosia* and *Leptæna*	8
	Rusty-brown, coarse, ferruginous sandstone, *Spirifer*, &c. Fine white sandstone with *Fusulinæ*, *Orthis*, &c. ...	15
	Black coaly sand or sandstone, with much pyrites and many fossils, *Aulosteges*, &c.	
5. SPECKLED SANDSTONE ...	Lavender clay	10
	Red and white sandstone	30
	Lavender clay	

The rocks are so disturbed and overrun by débris in some places, that a fairer estimate of their thickness could not be formed. Besides this, the sections are often oblique, giving an apparently greater thickness, while slips and slight local changes in the beds make the order appear somewhat different in different places; the above table, however, gives a general idea of the succession. The alum-shales at the top of the section are divided into two bands by a zone of white sandstone, and though this might be merely an accidental occurrence, the arrangement coincides with the fine Chicháli section Trans-Indus, suggesting the possibility that these two zones of alum-shale may represent the larger bands of Chicháli, and that the intervening sandstone may be of cretaceous age. A break or irregularity in the succession which is seen Trans-Indus is not, however, observed here, and the similarity, so far as it extends, must only be taken for what it may be worth.

Alum-shales.

East-north-east of Ámb village, a track leads by some Buddhist ruins up to Kángrawála summit, a lofty hill of carboniferous limestone, 3,920 feet above the sea. The strata of this hill are most curiously arranged in an inverted fold, the outcrop being to the north and producing fine cliffs of 400 and 500 feet high at least (see fig. 44, plate XXIII). At the summit of this hill, too, there are some strange natural funnels; these when visited, late in the evening, were emitting volumes of hot damp air, the moisture of which condensed upon mosses and other damp-loving plants which surrounded their mouths. The reason of this occurrence was not clear; some decomposing pyritous beds, whence heated air or gases might ascend, may have been caught in the fold, or may exist in the limestones; the weather was hardly sufficiently warm or the evening sufficiently cold to have produced the difference of temperature and an upcast draught, supposing the air had access below. To the east-by-north of this hill, a long fault, apparently the continuation of that passing north of Jalár, separates the carboniferous from the nummulitic limestone along a line parallel to the course of a

Kángrawála hill.

Exhalations.

rocky stream. At the point where this fault enters the Ámb gorge, some nummulitic limestone forms a crag, resting against the foot of a lofty cliff of carboniferous limestone, and near this crag about 150 or 200 feet of soft sandy beds belonging to the jurassic group are also crushed against the limestone; some of the same beds as occur in the neighbourhood of Ámb being thrown into a nearly vertical position, close to a place where old alum-works were reported to have existed. At this point were seen—

Head of Ámb glen.

		Feet.
NUMMULITIC ...	4. Black shales, gypseous and pyritous	54
	3. Lumpy lower nummulitic limestone	27
	(Variegated red band with some flaggy shales wanting here.)	
	2 White sandstones with black shales	28
JURASSIC ...	1. Crimson clays and soft white sandstones ...	50

And in another place close by—

		Feet.
NUMMULITIC ...	6. Lumpy nummulitic limestone	indistinct.
	5. Variegated red band, flaggy beds and shales ...	
	4. Very black shales	12
	3. Dark grey shales	15
	2. Rusty-shaly beds	30
JURASSIC ...	1. White sandstone	100

The difference between these two small portions of the series shows how these beds are liable to vary and how little their detailed character is to be depended upon, their identification in the absence of fossils being only determinable from general features.

Round the head of the glen, faulted against the nummulitic limestone by an east and west fracture not far from the main fault, and also reappearing among the hills of the nummulitic country between this and Uchâli, the white and red, sandy and argillaceous, jurassic beds may be seen cropping out from beneath the whiter nummulitic limestones, and they also appear along the main Jalár fault southward of the last-named village. The triassic beds below are also occasionally visible.

These jurassic and triassic beds pass also from the head of the Ámb glen along the southern brow of Sakesar mountain, the variously coloured bands of the

Southern glen along the Sakesar.

jurassic series forming a sort of escarpment below the talus of the nummulitic cliffs, while the underlying triassic rocks are more concealed. The carboniferous group forms another ledge of 200 to 300 feet in depth, below which the "speckled sandstones" appear, with a thickness of 250 to 300 feet, the lower 50 being of coarse white sandstones. The "purple sandstone" below is but slightly represented, and it is doubtful if in some places here that group is not entirely absent. Where represented it sometimes consists of 90 feet of dark shaly conglomerate with metamorphic pebbles. Beneath the "speckled sandstone" group the lower slopes are greatly confused by the long lines of slipping already mentioned, but the "red salt-marl" is frequently seen. The stream at the bottom of the glen flows for more than a mile among vertically bedded, craggy, displaced masses of the carboniferous limestone, forming a hard bar in the valley, and extending together with a part of the triassic beds, to west-by-south along the Sakesar side of the main fault. On the opposite side of this the "speckled sandstone" and "red marl" come together, with but a small representative of the "purple sandstone" between, or in places without any of it at all. The main stream having left the vertical part of the carboniferous limestone, crosses the sandstones and marl, then crosses the Ámb village fault, and flows between banks of carboniferous rocks again; below these it has the limestones on the left and the "red marl" on the right down to the place where the rocks on its banks have been already described.

Sirán-ki-dok.

High up above the glen of Ámb and on the opposite side from Ámb village is the small hamlet of Sirán-ki-dok, situated on a spur from Sakesar. Hereabouts the higher ground is all formed of nummulitic limestone, undulating or dipping to the northwards, towards the nummulitic synclinal of Sakesar peak, while in a north-westerly direction these beds dip at high angles to the north-east. This nummulitic limestone sends out a tongue to the southward from the village (nearly on the watershed between the Ámb glen and the Bazár Wán) around which both the jurassic and triassic

beds crop out, resting on the carboniferous limestone, the whole series passing off on one side along the Ámb glen, and on the other along the north-eastern side of the Bazár Wán. From the high ground looking in the latter direction the four groups, Nos. 6, 7, 9 and 11, can be well seen striking steadily off to the north-west, with much less of the confusion and concealment occurring on the northern side of the Ámb valley.

The following succession occurring in the vicinity of Sirán-ki-dok is taken from the notes of Dr. Waagen and myself, many of the details being from the former :—

NUMMULITIC ...	Nummulitic limestone	disturbed.
	Alveolina beds	
	Nummulitic limestone	Feet.
	Yellow nodular marls, *Nummulites*	20
	Brown marls, upper part hæmatitic	15
	Grey nodular marls, no fossils	8 to 9
	Variegated cavernous sandstones	25
	Hæmatite	10
		79

		Feet.	Inches.
JURASSIC ...	Alternations of brown sandstone and hard yellow marl	12 to 15	0
	Brown coarse sandstone	30	0
	White cavernous sandstone	3	0
	Coarse rusty sandstone, conglomeratic in parts ..	45 to 50	0
	White sandstone	6	0
	Hæmatite	5	0
	Yellow sands and sandstones with chalcedony ...	6	0
	White sandstone, many ferruginous spots... ...	50	0
	Liver-coloured sandstone	10	0
	Soft rusty sandstone	8 to 10	0
	Light rust-coloured sandy limestone with pebbles or concretions of grey marlstone	2	6
	Soft sandy bed	1	0
	Liver-coloured sandstone with ripple-mark ...	2	0
	Rust-coloured soft sandy beds...	7	0
	Hard sandstone, ripple-marked	1	6
		199	0

		Feet.	Inches.
TRIASSIC ...	Very hard rusty limestone with numerous sections of *Ceratites* or *Ammonites*, gastropods and bivalves...	3	0
	Soft yellow sandy beds	3	0
	Hard rusty-coloured layer	1	6
	Grey cavernous sandstone	3	9
	Very hard grey limestone, glauconite, and bivalves ...	6	0
	Soft yellow sandstone	60	0
	Thin bed of sandstone with many indistinct bivalves ...	0	3
	Hard brown bed with numerous pebbles of limestone...	1	6
	Grey limestone with numerous bivalves	3	0
	Thin-bedded limestone with *Ceratites*	10	0
	Sandstone and limestone with *Ceratites*	20	0
	Ceratite marl, badly seen	30	0
	Brown conglomerate bed	1	6
		147	9
CARBONIFEROUS	Rusty dolomite	6	0
	Light coloured sandstones, *Bellerophon*, *Athyris subtilita*, *Dentalium* &c. ... ... Compact dolomitic, sandy and fossiliferous, grey, carboniferous limestone ... ... Sandy and ferruginous beds	About 350	0
SPECKLED SANDSTONE.	Speckled sandstones with coarse white sandstones below	300	0
PURPLE SANDSTONE.	Purple sandstone, conglomeratic shale	100	0
SALINE GROUP.	Salt-marl	Uncertain.	

Sakesar.

Sakesar mountain rises above everything else in the Salt Range or adjacent country. It has somewhat of a crescent-shape in plan, the convex side being turned towards the south; a spur to the north-east connects it with the most lofty portion of the anticlinal lying in that direction; and high ground, but gradually declining, stretches away as a narrow ridge to the north-west. From the higher points the stony ridges of the nummulitic limestone country and the Son plain with its salt-lake are overlooked to the eastward; more abruptly broken country to the south; the long valley, between nearly parallel chains of hills, called the Bazár Wán, to the westward; and to the north long undulating slopes, broken here and there by crags, lead the eye downwards to the great Potwár plateau.

The nummulitic limestone of the summit of the mountain does not form a horizontal cap, but is bent into anticlinal and synclinal curves, having an east-and-west direction or following the crescent-shaped form of the hill; valleys having been excavated and minor ridges left between, with only a very slight relationship to the contortions of the strata. On the crest of the mountain the nummulitic limestone beds dip generally southwards, but are so curved, at some distance down the hill-side in that direction, as to crop outwards from the surface. On the northern slopes the beds are inclined with the ground, but they have been cut through by denudation, leaving some of the basal nummulitic hæmatite exposed, as well as one large and several smaller patches of the jurassic rocks. The latter are here chiefly white sandstones and rusty-yellow earthy beds with calcareous layers containing *Terebratulæ*, *Belemnites*, &c.; they are conformable to the nummulitic beds, and dip with the northern slope of the ground. At the foot of the mountain in this direction and for some distance up its flanks, the surface is covered with debris of the nummulitic and tertiary sandstone groups, the latter rocks being exposed in the deeper stream-courses at a considerable distance from the limestone of the mountain side.* The structure of Sakesar and adjoining ground will be seen from the section, fig. 45, Plate XXVI. Near the base of the red earthy zone overlying the lower tertiary sandstone beds and in a direction north-by-east from Sakesar summit, is a salt watch-house placed to guard some saline streams and efflorescence similar in character to that which frequently occurs in the lower portion of these tertiary sandstones and clays, but in larger quantity than usual.

Salt chowki.

* Some very good bungalows have been built near the summit of Sakesar to supply the want of a sanitarium for Shahpur and Miawáli stations. A good road leads to these from the Son plateau, and a very bad one down the northern slopes *viâ* Miawáli Dok to Namal. The situation is lofty but bleak, there being little vegetation, and supplies have to be brought from Uchháli, a distance of several miles.

SECTION XI.—CHIDERÚ HILLS AND NARROW PART OF THE SALT RANGE.

Hills west of Sakesar.

The hills to the westward of Sakesar are divided into two principal groups by the rugged valley of the Bazár Wán running in a north-west direction towards Músa-khel. Both of these groups are closely connected with the Sakesar mountain, the north-eastern one being a continuation of it and the other united by the spur of Serán-ki-dok.

Series.

The latter group has been alluded to as the Chiderú hills. These are in places lofty, one summit rising to within a foot of 3,000 feet, and the group has a general north-west and south-east extension. All over these hills the carboniferous limestone is largely exposed, the beds rolling or contorted, dipping in various directions; the rocks consisting of the usual light-coloured compact or crinoidal, and sometimes magnesian, limestone, some more sandy rocks and shaly beds. Beneath these the "speckled sandstone" group, with its coarse conglomeratic sandstones, grey and lavender clays, and red ferruginous shales, very frequently makes its appearance. The "purple sandstone" group is thinner and more fugitive in its occurrence, and the "red salt-marl" is seen in very many places, both among the hills and along their outer portions. Above the carboniferous limestone near Chiderú, there is a considerable development of the triassic rocks, and at one spot on the opposite side of the hills from that village a small fault-enclosed patch of the nummulitic limestone occurs in the Bazár Wán.

Faults.

Two considerable but irregular lines of fault traverse these hills and coincide generally with the direction of the ranges on either side of the most lofty ground; there are also, both in the lower outer regions and within among the hills, very numerous dislocations of the character usual along the whole southern face of the range. These dislocations are most numerous and most complicated from the opening of the Ámb glen to the hills above Golewála-keri or Dheda. (See fig. 46, Plate XXVII.)

Golawála-keri.

Near the latter place the outer slopes of the hills are covered with debris and displaced masses of the carboniferous limestone, and in the gorge opening there upon the plain, the rocks are much affected both by slipping and by contortion. The dark greyish purple conglomeratic shale representing the "purple sandstone" in places in the Ámb glen is so entangled with the red marl as to appear to dip beneath it; and near this, for 80 or 100 yards, vertical white and purple sandstone, red shaly bands and liver-coloured sandstones, are crossed by the stream. In a slipped mass perhaps somewhat internally disarranged, the following succession occurs :—

Shaly clays and white sandstone layers of the "speckled sandstone" group, thickness obscure.
(*Slip or fault.*)

		Feet.
TRIASSIC ...	8. Greenish grey, hard, sandy shales or clays with orange bands (very like some of the upper tertiary rocks)	200
CARBONIFEROUS	7. Sandstones and silicious limestone	?
	6. Dark limestone and shales	100
	5. Dark grey compact limestone with shale bands ...	90
	4. Black shales	12
	3. Coarse sandy limestone with occasional black shale patches, corals and crinoid fragments	5
	2. Black shales, with yellow partings, and small white sandy layers	15
SPECKLED SANDSTONE.	1. Purple and grey shales or clays.	

Lower part of carboniferous.

From this it would appear that the carboniferous group is growing thin. Amongst the lowest of its beds here are a few dark-coloured sandy limestones with large *Producti, Fusulinæ,* &c., underlying a thirty-feet rusty, silicious, band with *Spiriferi.* The junction with the upper part of the underlying "speckled sandstone" is thus :—

		Feet.
CARBONIFEROUS LIMESTONE.	Dull earthy compact limestone, with spines of Echinoderms, *Bellerophon* sections, &c. ... White crinoidal limestone	about 280

IN EAST BRANCH OF OLAWALA GORGE

Fig. 4b

J Schaumburg Lith.

PLACE OF THE COAL SHALES IN BAKH RAVINE

		Feet.
CARBONIFEROUS LIMESTONE—*contd.*	Soft, white, crumbling sandy beds and hard bluish micaceous sandstone	50
	Rusty limestone	30
	Greenish sandy earthy beds	30
SPECKLED SANDSTONE.	Lavender clay	partly exposed.

North of village.

Within the hills northward of the village a large broken tract of ground, lower than that on either side, follows the direction of one of the faults previously mentioned. In this tract there is much of the red marl, some purple sandstone, and a broad space is occupied by the "speckled sandstone" group, the red marl cropping out into the Bazár valley. Westward of this ground, the carboniferous beds have been a good deal eroded, allowing the speckled sandstones to appear even high up among the hills.

Bazár Wán.

Golawála to Chiderú.

Between Golawála and Chiderú the outer hills are often formed of the carboniferous limestone, behind which stretches a narrow crooked zone of the salt-marl, associated with about 150 feet of the "purple sandstone" and portions of the overlying sandstone group supporting other masses of the carboniferous limestone.

Chiderú.

East of the village of Chiderú these groups occupy the outer face of the hills along the upper part of which the carboniferous limestone forms a well-defined line of cliffs about 250 feet in height, and on the slopes behind there is a thick mass of the triassic beds sloping downwards into a longitudinal hollow among the hills. The following is the succession across these beds, part of the list being extracted from Dr. Waagen's notes.

The "red marl," "purple sandstone," "speckled sandstone," and carboniferous limestone occur here north-east of a fault. South-westwards of the same fault are—

		Feet.
7. TRIASSIC ...	Greenish grey marls	20
	Rusty-coloured dolomites	
	Greenish grey marls	

		Feet.
7. TRIASSIC—*contd.*	Hard limestone with many bivalves and fragments of *Ceratites*	10
	Greenish ferruginous sandy marls and sandstone with *Gervilliæ*, *Ceratites*, and *Orthoceras*	10
	Hard sandstone with spinose *Ceratites*	5 to 6
	Greenish sandy shales and sandstones	50
	Bellerophon bed, calcareous sandstone	1
	Soft greenish sandstone	20
	Green marls	20 to 30
	Lower Ceratite limestone	10
6. CARBONIFEROUS.	Brown dolomitic sandstone with *Bellerophon* ...	100
	Calcareous layer with numerous fossils, *Producti* and *Ceratites*	10
	Yellow dolomitic sandy beds	30
	Grey clays	20
	White compact limestone	200
	Debris	
5. SPECKLED SANDSTONE.	Lavender clay .. . .; Red, grey, and greenish sandstone, with lenticular masses of yellow quartzite; light-coloured sandstones and shaly, flaggy bands	450?
2. PURPLE SANDSTONE.	Deep purple sandstones	200
	Purple shaly lower part	100
1.	Gypseous salt-marl	250 to 300

The salt-marl disappears beneath the boulder-zone of the plains beyond the faulted lower groups named immediately before this list, the ground is chiefly formed of carboniferous limestone the whole way across the hills to the Bazár Wán.

Triassic section.

East-by-north of Chiderú in a country likewise mainly occupied by carboniferous limestone, the following section across another part of the triassic beds was noted by Dr. Waagen:—

		Feet.
	Debris.	
PERHAPS BASE OF JURASSIC.	Variegated sandstones	10
	White sandstones	3
	Purple and red ferruginous sandstones with sulphur-coloured stripes	10

		Feet.
7. TRIASSIC	Hard rusty dolomite, with a *Cardinia* and *Anoplophora*	3
	Green marls	6
	Rusty dolomite	3
	Green sandy marls, with thin sandy layers and gypsum	20—30
	Hard limestone with many bivalves	2
	Rusty sandstone, fucoids	3
	Grey sandstones with *Ceratites*, *Gervillia*, *Orthoceras*	3
	Rusty sandstone, with fucoids	2
	Grey marls with flaggy limestone	2
	Grey marls, nodular marls, and hard limestones, with spinose *Ceratites*	50
	Ceratite sandstone, not clearly seen, with extremely large species of *C. Flemingii*	10—20
	Green Ceratite marls	60—80
	Flaggy lower Ceratite limestone	3—5
	Grey sandstone	6
	Green marls	4—5
6. CARBONIFEROUS	Yellow soft sandstones, with concretions; filled with fossils, *Bellerophon*, *Athyris*, *Dentalium Herculaneum*, &c. (Top of the carboniferous limestone group.)	

Some of the grey and rusty beds in this patch of the triassic rocks very much resemble the upper tertiary sandstone beds, and the white and variegated beds at the top of the series detailed may be probably the base of the jurassic group.

North-west of Chiderú.

To the north-west of Chiderú the carboniferous rocks cover nearly all the hilly ground, and form besides a small outlying hill, opposite to the mouth of the Bazár Wán, in which the following succession of beds was observed:—

		Feet.
CARBONIFEROUS.	8. White crinoidal and grey compact thin-bedded limestone...	36
	7. Red marbled vesicular limestone	3
	6. Light-coloured compact limestone, with *Echinus* spines and *Bellerophon*	7
	5. Compact limestone	10
	4. Cherty limestone	15
	3. Reddish limestone	2
	2. Cherty, yellowish, magnesian limestone	5
	1. White crinoidal and coral limestone, 6 feet seen, but may be	60

Mouth of Bazár Wán.

In the dry stony channel here the banks expose many slips, and some of the limestone is brecciated-looking and magnesian, certain beds on the left side of the channel near its mouth being crowded with finely-weathered corals, &c. Just beyond this a fault, or perhaps two, are marked by the wedging into the section of a small mass of the speckled sandstones. Further up the stream on the side of the hills next the open stony flat of the Bazár valley, the red salt-marl is exposed, and here some old salt-mines are said to exist but to be inaccessible. Small portions of the purple and speckled sandstone groups are also seen, much cut up by faults (or slips), and the hills above the right side of the Wán are covered by contorted carboniferous limestone.

End of these hills.

The Chiderú group of hills ends in some small isolated elevations rising from the stony zone east-by-south from Músakhel. The same limestone in these is contorted, in places rusty, cherty, and magnesian, or pink, whitish, crinoidal, or grey; the hard rusty-coloured bands having small ferruginous projecting pieces of corals, crinoids, or Echinid club-spines; and the grey beds containing sections of *Bellerophon* or *Goniatites* and some other fossils.

The Bazár river between these Chiderú hills and the narrow part of the range from Sakesar north-westwards does not seem to flow out at the natural mouth of the valley, but turns to the south and escapes through the hilly country towards the Thar and the Indus plains. On this side of the glen at the upper waters of a tributary branch of the main stream, is the small mass of the cherty nummulitic limestone previously mentioned, faulted into the carboniferous limestone and nearly surrounded by it, without any appearance of the intervening beds. Whatever the process by which this mass became so placed, it must have undergone considerable disturbance, for its layers are much contorted, being in some places vertical and in others horizontal.

Where valley becomes contracted.

Where this Bazár river-valley becomes contracted and hilly, the stream flows between high banks of the carboniferous limestone above which, on the side of the

glen forming the north-western extension of Sakesar, the triassic, jurassic, and nummulitic formations dip at high angles to the north-east, the following being the general arrangement of the rocks:—

		Feet.
11 Nummulitic	Nummulitic limestone	300 to 400
	Soft light-coloured calcareous clays . .	55
9 Jurassic ...	White and red and rusty sandstones alternating with purple and hæmatitic shaly beds	230 to 300
	Yellow earthy beds	90
	Light-coloured sandstone and red shale...	100
	Rusty-yellow sandy and clayey beds . .	25
	White coarse and fine sandy beds	120
7. Triassic . .	Green shaly and flaggy limestone and sandstone beds	300 to 350
Carboniferous.	Carboniferous limestone	250 to 300

Ridge from Sakesar to Namal.

The groups below the carboniferous where this valley opens present a different appearance from those to the eastward of Ámb. The red salt-marl is succeeded by dark brownish-purple splintery conglomeratic clay; the pebbles being of red granite, quartzite, amygdaloid, trap, and so forth, the metamorphic varieties predominating; so that it would seem as if the "purple sandstone" was not only growing thinner to the westward, but also changing its character in a north-easterly direction, the usual type of these beds being generally found along the outer or southern side of the hills; but the conglomeratic shaly mass (for there is but little stratification in it) being developed at a distance of a few miles, and more within the hills. It must, however, be observed that no good example of transition has been detected, even though the conglomeratic shale occurs close to some of the "purple sandstone" beds at Golawála; hence I cannot assert that these conglomeratic shales are absolutely a part of the lower purple sandstone; they might just as well belong to group No. 5.

Change in purple sandstone group.

Just above these boulder-beds, which vary a good deal in thickness, being sometimes 100 feet or even more, there is frequently a fifty-feet

band of green conglomerate, likewise formed of crystalline fragments, and above it, here and there, are seen peculiar black, powdery, carbonaceous, shaly or coaly layers, from a few inches to nearly a foot in thickness. These are again overlaid by the lower coarse white sandstones and red earthy alternations of group No. 5. The carboniferous limestones succeed; the upper lavender clays of the inferior groups are not so strongly represented as to the east; and the overlying limestone is frequently dark and thin-bedded, the whole carboniferous group being apparently thinner than previously. The triassic beds present their usual character, with perhaps less of the greenish marly shales; but the jurassic formation has increased, its strong white sandstones contain quartz pebbles, and its more flaggy beds many obscure plant fragments. The lower soft white beds of the nummulitic limestones are strongly developed, the whole group is much contorted towards Sakesar, and the junction of the nummulitics with the overlying sandstones is concealed.

Carboniferous layers.

General observations.

From the place where the Bazár valley commences to open, onwards to where the narrow part of the range is crossed by the Bakh ravine between Namal and Músakhel, the red salt-marl is but little seen, and the overlying rocks show a tendency to form an anticlinal curve, the lower strata on the south-west side of the ridge being more or less nearly horizontal, but the dip increases as the ridge is ascended, until at the crest (which partly coincides with the lower boundary of the nummulitic limestone), the whole of the beds dip at 45°, 50°, and 55°, to the north-east. Above the left bank of the Bakh ravine, the summit of the ridge is formed by the jurassic beds here containing bands of limestone, in addition to the rocks above mentioned. The nummulitic rocks still keep their high angle of dip, and the lower parts of the tertiary sandstones run upwards on their steep slopes. These two last groups form a deep longitudinal valley with almost inaccessible sides, excavated along the strike of the softer tertiary beds. The north-east side of this long valley is capped at a

Músakhel.

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height of about 1,150 feet by a thick unconformable patch of coarse conglomerate of much more recent aspect than the grey and greenish tertiary sandstones underneath it, and probably of post-tertiary age. The escarpment of this conglomerate, which is more sandy below, forms cliffs of nearly 100 feet close to the town of Namal, which is built upon it, and a smaller portion of the same deposit, showing the unconformity still better, rests above the opposite bank of the stream (see Plate XXIX).

Bakh ravine.

The Bakh ravine here gives an interesting and complete section through all the beds forming the narrowest part of the range, from the carboniferous limestone upwards. It is not, however, practicable to follow the stream the whole way through the gorge, on account of the precipitous character of its channel. On the Namal side the highest rocks seen are the unconformable conglomerates just mentioned. Underneath these is a thickness of 1,200 feet of grey and greenish tertiary sandstones, with the usual argillaceous beds, dipping north-eastward at 60°, in immediate and parallel contact with the upper surface of the nummulitic limestone. Rather lower than half-way down in this limestone is a strong band of black, coaly and pyritous shales (see fig. 47); and the underlying part of the limestone is as usual lumpy and nodular. Just at the base of the group are some beds filled with fossils of the Val Ronca eocene type,* very few of which can be extracted from the rocks.

Below these are ferruginous white and purple sandstones, yellow mud-stones, yellow earthy limestones and coarse sandstones of the jurassic rocks underlaid by the greenish shales and flaggy limestone beds of the trias, the carboniferous limestone forming an anticlinal arch below all. The section is as follows (see fig. 48, Plate XXVIII) :—

		Feet.
13. POST-TERTIARY.	Strong sandy conglomerate	80 to 100
	Unconformity.	
12. TERTIARY SANDSTONE.	Grey and green sandstone with some reddish and greenish clay bands	1,200

* According to Dr. Waagen.

		Feet.
11. NUMMULITIC	White and pink marble	100
	Thin-bedded white cherty limestone	80
	White limestone with black chert	50
	White and grey calcareous shales, fossils scarce, Gastropods and crustacean fragments	100
	Black pyritous and coaly shales	150
	Darker limestone and grey shales with pyrites, beds lumpy below and one sandy bed: about	60
	Yellow and white sandstone, no fossils .. .	9 to 10
	Grey clay with three layers of brown sandy limestone, small *Nummulites* very scarce, *Nautilus, Nerita, Turritella, Natica, Crassatella,* &c., difficult to obtain ..	15
	Cavernous brown sandstone, no fossils	6
	Grey clay with gypsum, large oval concretions and hæmatitic veins	40
	Hæmatite	6
		617
9. JURASSIC ...	White and yellow splintery limestone with many small fossils, *Nucula, Natica,* &c., 15 feet ... ... Variegated reddish and light-coloured sandstones, dark grey shales and flags with plant-remains in bad preservation	200
	Yellow limestone, grey inside, crinoidal below, earthy and magnesian in places	150
	Grey and variegated hard sandstone, thick white ferruginous and banded sandstone	80
	Dark micaceous flags and soft and hard white sandstone, conglomeratic in places; dark grey and yellow crinoidal limestone bands in the above; grey, white, and purple sandstones, limestones, shales and flags	100
		530
7. TRIASSIC ...	Thin grey limestones	6
	Sandstones	8
	Thin grey limestones with *Ceratites*	13
	Calcareous sandstones and gypseous shales, weathering green, *Ceratites*	250
		277

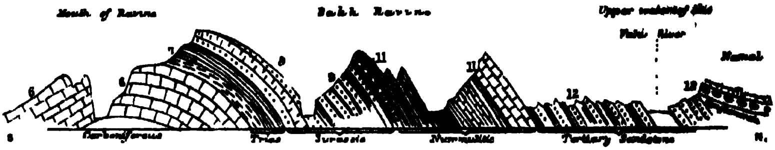

Fig 48. Section through the Bakk Ravine, about natural scale, 3 inches = 1 mile

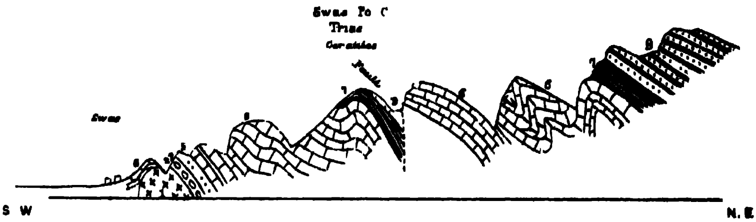

Fig 50 Rough sketch of a section close by Swas_to show contortion

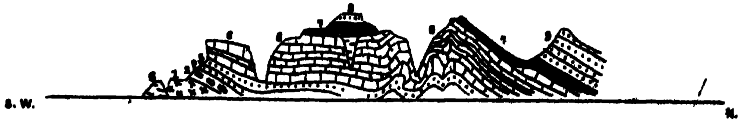

Fig. 51 Another rough sketch of a section near Swas.

		Feet.
6. CARBONIFEROUS	Thin-bedded limestones and shales, sandy limestones, thick-bedded black and dark-coloured limestones, with a few shales, *Goniatites*, *Orthoceras*, *Spirifer*, *Productus*, *Fenestella*, *Terebratula*, Crinoids, &c.	250 to 300

The principal differences between this section and those of the country previously described are, that in the jurassic formation a strong bed or zone of limestone is present, and the coaly shales of the nummulitic group, instead of occurring near its base, are at a considerable height in the formation, showing a lateral change in the earlier conditions of that period. The hot and sulphurous springs of this Bakh ravine have been already mentioned (page 48); they do not seem to be directly connected with the presence of any particular formation, as they occur in three of these—the carboniferous, jurassic, and nummulitic groups—in different parts of the ravine.

The tertiary sandstones north of the ravine have a white, saline efflorescence, which may also be observed where the stream traverses the jurassic beds. At a height of 450 or 500 feet (by aneroid), over the right cliff-bank of the gorge, rounded river-pebbles were found in sufficient quantity to suggest their having remained there since the stream ran at that level. For about nine miles in a north-westerly direction, along the

North-west of Bakh ravine.

Namal ridge, the nummulitic limestone retains its steep steady dip to the north-east (fig. 47, Plate XXVII), and its hard beds form scarped projections overlooking longitudinal valleys cut out of the softer bands to the south-west. High ground on the western sides of these valleys is occupied by the jurassic rocks, and below these the triassic and carboniferous groups are much disturbed, broken, and concealed, small masses of the "salt-marl" and adjacent sandstones being introduced by faults among the sandy and compact limestones with *Fusulina*, &c., of the carboniferous group. To the eastward of the ridge the ground forms part of a wide, flat plain, in which, for want of fall, *khudderas* have not been excavated by the atmospheric waters. Behind the village of Búdi-khel the gypseous "salt-marl" forms a hill 350 feet or so in height, at the back of which is a

considerable quantity of the dark conglomeratic shale, with metamorphic pebbles, forming or replacing the lower part of the "purple sandstone" group.

Búdi-khel.

The water used at this village is brought from a glen about a mile and a half to the northward, in which the thin-bedded, brown, rusty, fossiliferous and grey limestones of the carboniferous group are seen, resting immediately upon the upper clays of group No. 5, here brightly coloured and variegated, a band of grey clay coming next below the limestone. In this glen also some of the red gypseous salt-marl is directly in junction with beds of the "speckled sandstone" group, all the rocks being much disturbed. In the hills above, the white and grey shaly clays of the nummulitic group have again hard limestones both above and below them; and in the jurassic group below, ferruginous, purple and white, flaggy or solid, fine and coarse or conglomeratic sandstones alternate with hard yellow marls, or lithographic limestone bands, containing brown crystalline hæmatitic nodules. The triassic group occurs in its usual place, and a large tract among the interior hills is occupied by the carboniferous limestones, &c.

Shuriwáli glen.

In an angle of the hills about two and a half miles north-west of Búdi-khel is the Shuriwáli glen, round which the carboniferous, triassic, and jurassic formations bend in a horse-shoe form. Beneath the carboniferous limestone some 500 feet of the "speckled sandstones" crop out. They are dull crimson and white, variegated and grey, with purple bands above, while the lower part is a mass of dark conglomeratic shales and clays, with green layers and black carbonaceous bands. The junction between these beds and the underlying highly gypseous red "salt-marl" is very indistinct, and there are indications of one or two narrow bands of the red marl alternating with the lower part of the blackish conglomeratic shale. It is, however, hard to speak with certainty of so incoherent and soft a mass in a country where dislocation prevails to the extent which it does all along the outer hills of this neighbourhood.

Carbonaceous bands.

An old mine occurs here, said to be in red salt, but it has not been worked for many years, and the ground having slipped, the mine is inaccessible. The rocks around this glen dip at high angles on all sides away from the excavation.

Salt.

SECTION XII.—TREDIAN HILLS.

Tredian.

The ridge from Namal expands where it joins the Tredian hills, and the nummulitic limestone which forms the steep eastern slope of the former spreads out with many undulations and contortions over the higher ground. At the termination of the Namal ridge west of Thámbawáli, a narrow, sharp, anticlinal curvature of these limestones occurs, a synclinal between this curve and the main nummulitic mass being occupied by the tertiary sandstones faulted against the latter. On the opposite or western side of this mass faults also occur, dropping portions of the nummulitic limestone among the jurassic rocks, which here, partly from increased thickness and partly from undulating horizontal extension, occupy a much greater space than they do anywhere else on the range. These rocks consist of coarse conglomeratic red and white sandstone, red and variegated clay, ferruginous sandy beds, with obscure plant fragments and yellowish or grey calcareous mudstone or fine-grained earthy limestone, like lithographic stone. (The red and white and ferruginous rocks of the Tredian hills present striking lithological similarities to the jurassic rocks of Kachh (Cutch).)

The heights.

Towards Swás.

Some hard limestones in these beds form a horizontal escarpment overlooking Búdi-khel from the north-west, and among other obscure traces of fossils contain a few fragments of strongly-ribbed Ammonites. At the foot of the escarpment the Ceràtite beds of the trias occur, following the sinuous margin of the jurassic group to the north-west, and surrounding some outlying patches of that formation resting on the carboniferous limestone hills over Swás. The outer edge of the latter formation, the whole way from the Suriwáli gorge to Swás, is greatly broken and dislocated, some-

times extending outwards to the plain and sometimes interrupted, allowing the "red salt-marl" and the overlying "speckled sandstone" groups to appear below it; but the "purple sandstones," unless represented here and there by the dark conglomeratic shales with crystalline blocks (as at Swás village), are entirely absent. (See section, fig. 50, Pl. XXVIII.)

Swás.

In the neighbourhood of Swás the whole of the rocks are greatly contorted; they are very often vertical or even inverted, the carboniferous limestone here making some of the roughest and most impracticable country in the range; but the general succession and the dip of the rocks is from south-westward to the north-east and north-north-east. The trias is less strongly developed than before, and much less in thickness than the jurassic group. The carboniferous limestone hills are often capped by the lowest beds of the trias, and fine precipices are composed entirely of the former. The "speckled sandstones" still have their accompanying clays above, while beneath them is a mass 150 feet in thickness, of the purplish black conglomeratic clay with metamorphic pebbles, associated with and underlying which is the gypseous red salt-marl. (See sections, figs. 50 and 51, Plate XXVIII.)

Succession near Ghari.

Further north-west the triassic beds may average only about 100 feet in thickness. The carboniferous limestones below often contain much chert, both black and white; while grey conglomerates and sandstone bands occur in the dark conglomeratic purple clay above the salt-marl. In this dark conglomeratic mass near Ghari some grey limestone pebbles were observed, and also layers of a calcareous nature with thin shaly bands, the dark earthy lower portion being 188 feet thick. Immediately over the earthy part is a large boulder-conglomerate containing blocks of granite, syenite, and other crystalline rocks two feet in diameter; this conglomerate, if it has not slipped upon itself, may be 155 feet in thickness. The speckled sandstone succeeding is not particularly well exposed.

The carboniferous limestone is thinner-bedded and of darker colour than usual; it is magnesian in places, and contains brown sandy bands

and a fine dark shale in its lower parts. *Producti, Spiriferi, Corals,* and several other fossils occur in it.

Overlying this group are 100 feet or so of flaggy limestone crowded with sections of *Ceratites, Bellerophon,* &c., and passing upwards into 80 feet of shales, weathering to a greenish clay, and containing thin layers of limestone and flaggy sandstone, hard and rugged, with annelid tracks and other markings on their surfaces. Among these some more prominent bands of sandstone also occur, the whole representing the triassic group.

In the lower part of the jurassic beds, a thick, rusty, soft sandstone contains carbonaceous markings, and a few plant fragments sometimes resembling fronds of ferns. These are more numerous, though still indefinite, in a two-feet bed of shale which overlies the sandstone and passes beneath some hard calcareous bands, the whole, so far, being about 110 feet in thickness. Above these beds are 230 feet of grey and yellowish, compact, splintery, cherty limestone, overlaid by the upper, sandy, flaggy, rusty and variegated beds of this jurassic formation, in which contortion and crushing often obscure the succession. In the very highest part of the group are 60 or 70 feet of dark, compact, fossiliferous limestone, full of bivalves, succeeded by 10 feet of lumpy, grey, compact limestone containing *Corbulæ,* and divided by a few bands of greyish calcareous sandstone. A small blank space then occurs in the section, above which are red hæmatitic and blue shaly bands, passing up into 30 feet of thin, earthy, nummulitic limestone, immediately succeeded by 300 feet of the more solid beds of that formation, which seems in this vicinity to have much more than its usual thickness.

Bargír *kas* and neighbouring hills.

One of the wildest glens in the country* is that called the Bargír *kas.* It is not practicable to ascend this ravine from its mouth, the way being barred by cliffs of

* The hills on the south-west side of the Tredian group between the neighbourhood of Ghari and that of Swás seem, in addition to numerous others given them, to possess the two names "Jella" and "Bargír."

the carboniferous limestone which near this runs out upon the plain, but the upper part may be reached by ascending over some "red salt-marl," up a slope of the "speckled sandstone," No. 5 (the intervening "purple sandstone" being absent), edged by cliffs of the carboniferous beds which dip towards the valley, and support the shaly and flaggy beds of the Ceratite-bearing trias. The latter being passed, the variegated and calcareous beds of the jurassic formation are reached, the section, so far, being as follows, according to my own observations and some notes of Dr. Waagen's made in this neighbourhood:—

Groups.		Feet.
No. 9.	Variegated beds of the jurassic much broken up ...	200 to 300
	Yellowish marly layers	15
	Compact splintery limestone, dolomitic, brecciated, light grey, yellowish or reddish (this rock would make a pretty marble)	100
	Yellowish red sandy limestone or calcareous sandstone, contorted	50
	Two beds of rusty limestone	6
	White sandstone, flaggy in upper part	30
	Grey and rusty limestone with many bivalves	10
	Thick-bedded red sandstone	15 to 20
	Whitish thin-bedded sandstone	3
No. 7.	Glauconitic pisolitic limestone, the grains of lime not iron, *Ceratites* and *Rhynchonellæ*	10
	(In this band is a bed of conglomerate, mostly of large limestone fragments, some of crystalline rocks.)	
	Greyish-green sandy marls	50
	Lower Ceratite limestone indistinct and mostly concealed by a—	

Fault.

No. 6.	Upper carboniferous, very slightly developed but full of fossils	6 to 10
	Compact carboniferous limestone, more than	100
	Dolomite	50
	Lower carboniferous, sandstones full of fossils	?
No. 5.	Lavender clay.	

Further up the ravine leads through a natural tunnel made by the stream through a mass of the carboniferous limestone, introduced by faults or slips. Beyond it the jurassic rocks are again reached, occupying one side of the valley, while high up on the other is the

escarpment of the nummulitic limestone. Among the highest of the jurassic beds here the following were observed, dipping at 35° to north-by-east:—

Group.		Feet.
No. 9.	Variegated red and white sandstones	180
	Yellow clay rock	12
	Cherty compact limestone	150 to 200
	Soft sandstones with black shale layers, carbonaceous markings, and yellow partings	15
	Yellow brecciated limestone	16
	Blue shale with grey flaggy layers	8
	Hard calcareous sandstone and limestone, magnesian, yellow and crinoidal	20
	Soft white sandstone, blue-black and grey shales ...	5

From the upper part of the above list there was room for 200 feet of beds before reaching the base of the nummulitic limestone, in which space only a twenty-feet band of red clay was exposed. Blocks of grey gypseous clay or shale, probably from the lower concealed nummulitic beds, lay about the ground. It is very probable that some part of this section is represented in that previously given, but the whole of the jurassic group may be fairly estimated at from 550 to somewhat over 600 feet. The trias formation was estimated in this country at 90 or 100 feet; it is composed of dark grey or greenish shale, and thin limestones as usual, the junction with the jurassic beds in another place being as follows:—

		Feet.	Inches.
No. 7. Lower part of Jurassic ...	Light-coloured purplish sandstone alternating with dark-grey shales	90	0
	Lumpy thin limestone with shell fragments ...	9	0
	Black shale with a lenticular bed of sandstone ...	2	6
	Black shales, grey flags, and white sandstones, flaggy parts with obscure plant remains ...	20	0
	Grey shales and flags	20	0
No. 9. Triassic ...	Thin limestone, shaly and flaggy with *Ceratites* ...	50	0
	Shaly and flaggy beds	50	0

Comparing this with the foregoing sections, it will be seen that within short distances these jurassic beds are liable to a considerable amount of change. Although not prominent in the ground so far described, there

is still to be noticed a thin calcareous band of golden oolite, entirely resembling that found in Kachh, and here also fossiliferous, with indefinite bivalve shells. This band lies between soft, white, red or yellow sandstones, with many obscure plants, and some compact limestone, with red and yellow hard argillaceous bands. It was found over the right bank of the Bargír *kas*, not far from the place where the passage up the glen is first interrupted.

Khyrabad.

North of the latitude of Ghari, the whole series of the Tredian hills strikes north-west out upon the plains, the boundary of which here takes a northerly direction; but a faulted local anticlinal curvature of the rocks towards Khyrabad again exposes below the prevalent nummulitic rocks, the jurassic, triassic, and some of the carboniferous beds. The axis of this anticlinal has an oblique direction differing by some 15° from that of the margin of the hills, so that the lower beds are exposed along the outer edge of these for a couple of miles, the carboniferous strata making a feeble effort to form the usual cliffs capped by the triassic and jurassic formations, overlaid in turn by the nummulitic beds. The section seen here* is—

		Feet.
No. 11. NUMMULITIC ..	Nummulitic limestone (coaly beds not seen, perhaps covered by debris at junction).	
No 9. JURASSIC	Yellow and brown marls, badly seen	50
	Variegated sandstone	20
	Glauconitic sandstone, with numerous *Belemnites* and *Gryphæa* in lower portion	30
	Grey clay, badly seen, canaliculate *Belemnites* ...	6
	Grey and yellow limestone, with irregular lenticular masses of golden oolite, *Rhynchonellæ*, *Terebratulæ*, *Astrea*, *Ammonites* (fragmentary), and canaliculate *Belemnites*	30
	Variegated sandstones	3
	Yellow and grey limestones, with numerous fossils which cannot be got out	20
	Variegated sandstones, with coaly bands	20

* This section is taken from Dr. Waagen's notes.

		Feet.
No. 9. JURASSIC,—*contd.*	Yellow and brown sandy limestone. with irregular layers, of golden oolite within ten feet, *Rhynchonella* and *Belemnites*; fossils rare	52
	Yellowish fine sandstone	10
	White coarse sandstones	20
	Red and purple coarse sandstones	50
	Brown and reddish splintery hard limestone, partly sandy, partly dolomitic	10
	Grey vesicular dolomite, with casts of small bivalves and gastropods	50
	Space of a quarter of a mile occupied by (discordant ?) soft orange and greenish sands and marly beds exactly like some upper tertiary beds: place and relations obscure: thickness fifty to eighty feet.	
	Variegated sandstones and marls (jurassic ?) faulted.	
No. 7. TRIAS ..	Very hard, brown sandy limestone and sandstone ...	100
	Space covered by debris.	
	Glauconitic limestone, with *Ceratites* ...	6 to 10
	Sandy marly bed	1
	Thin-bedded brown limestone, with *Rhynchonella* and *Ceratites*	3
No. 6. CARBONIFEROUS.	Grey sandstone, with *Bellerophon* and *Dentalium*, badly seen.	
	Carboniferous limestone, compact and full of fossils, which in the upper portion are very difficult to extract.	

Khyrabad hills.

On the western side of the hills here, particularly along the Barki nulla, there is a thick deposit of rubbly stream-like conglomerate and clay, forming cliffs 200 feet high, the fragments being of the local rocks. A couple of small mound-like hills near Khyrabad are formed by brecciated (and magnesian ?) limestone, with some sandstone and shales of the jurassic group, indicating the direction in which these rocks pass into the plains. The mass of the hills here is cut off from those towards Mári, by the open valley of a nameless river coming from behind the hills towards Jába. On the south-eastern side of this gap the massive, thin-bedded, and lumpy layers of the nummulitic limestone are seen to dip pretty steadily towards the east-north-east at 30°, underneath heavy masses of light, drab-coloured, gypseous clay, which lie along the

north-eastern flanks of the hills. The origin of this gypseous clay is not clear. It appears again in the neighbourhood of faulted ground, on the northern side of the gap which separates these hills from those near Mári, and it may be traced at intervals on the north-east flanks of the Tredian hills as far as the petroleum spring behind Jába (west).

North-eastern side of Tredian hills.

The north-eastern aspect of the Tredian hills is generally abrupt and steep, the undulating nummulitic limestone dipping at high angles beneath the tertiary sandstones of the Potwár or Ráwalpindi plateau. The latter rocks are exposed at several places close to the flanks of the hills, those beds nearest the nummulitic limestone being as usual greenish and grey sandstones; in places containing small pebbles, purple pseudo-conglomerate and red and greenish-grey shales, of the (locally) lower division of the tertiary sandstone group. These beds extend with many alternations along the base of the hills;* they are about 1,000 feet thick and are overlaid by the red, soft, clayey zone, here having a thickness of 1,200 or 1,400 feet. The softer grey sandstone and orange clay beds succeed, occupying the rocky portion of the neighbouring plateau and forming the sides and mass of many of its *khudderas*.

Towards the base of the red tertiary zone in the lower sandstones and pseudo-conglomeratic beds, only imperfect fragments of bone and one part of a reptilian tooth were found, the search for fossils in these rocks being generally almost fruitless.

Petroleum.

In the neighbourhood of Jába west, on the north-east side of the Tredian hills, and five miles from their termination, are the two petroleum localities referred to by others and fully reported upon by Mr. Lyman (Report on the Oil Lands of the Punjab, p. 38 *et seq.*). The oil comes from that part of the

* Detailed sections of these rocks measuring about 1,000 feet each are given by Mr. Lyman and Mr. Theobald, the former near Jába west, the latter near Jabbi (see Mr. Lyman's report, p. 39, and Mr. Theobald's paper, p. 671). As the word "alternation" expresses almost the whole character of sections in these greenish-grey and red sandstones and clays, time was not taken up in measuring them.

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JABA OIL SPRINGS TRI DIAN

Fig 52

RA IF MARL EFT BANK OF INC E R MAR

Fig 53

nummulitic beds which forms their last undulation before passing downwards at a steep angle beneath the plateau. The petroleum issues out of a zone from 40 to 150 feet below "the top of the lime rock" according to Mr. Lyman; but when I visited the place, it seemed to spring from a position nearer to the uppermost layers of the limestone. How deep-seated the sources might be, there were no means of determining. The oil is at first green, afterwards changing to black, and the amount capable of being collected here from both localities was little more than one gallon daily. The springs are situated at the edges of the channels of the Chota and Bara Katta brooks, as they leave the hills, and just where these hills rise steeply from the lower ground. The oil-springs are so near the water—on which, indeed, much of the oil floats—that when these streams are in flood the whole accumulation of it is washed away. The oil does not issue by itself, but accompanied by water, and the locality would be a good one for making trial borings, as suggested by Mr. Lyman, though the existing springs are ill situated on account of the loss occasioned by floods. (See fig. 52, Plate XXX.)

The bed of the sandstone series which immediately succeeds the nummulitic limestone is itself calcareous and concretionary, containing a few nummulites and bearing more or less resemblance to the pseudo-conglomerate layers higher up in the series.

Native sulphur was formerly collected at Jába from gypseous clay deposits close in the vicinity of the petroleum springs, the water of which is charged with sulphurous gases; but when I visited the locality, the places pointed out, on being dug into, yielded only microscopic grains of a yellow mineral which might have been sulphur. The presence of the sulphur here and the gypseous nature of the superficial clay suggest the agency of sulphurous springs as a cause for the similarly gypseous condition of the great clay mounds before mentioned along the base of the hills north-by-west from this place.

Mári neighbourhood.

Between Khyrabad and Mári the older rocks form only low and not continuous hills along the margin of the plains, the largest being the salt-hill of Mári, and the

principal elevations of the neighbourhood being well-marked escarpments of the tertiary sandstones cropping to the south-west and dipping in an opposite direction at angles of 20° and upwards to 45°. The whole space is traversed by complex and often obscure faults, abnormally placing fragmentary portions of the series inconsecutively among others. The continuation of the range is here indistinct, the highest ground being a parallel ridge, three miles to the north-east, formed of the tertiary sandstones, &c., dipping in that direction, generally at low angles. Coming, as it were, from beneath these to the south-west are various red and grey sandstone and earthy beds, among which the red pseudo-conglomeratic bands contain small bone fragments and sometimes fragments of crocodilian teeth. These were observed at the foot of the ghât, on the road from Mári to Niki, eastwards of Súmbla-ki-Vándi.

Súmbla-ki-Vándi.

In the neighbourhood of the latter village the beds of the tertiary red zone predominate, undulating at low angles, and being cut off near Ainwa by a fault from the Indus towards the village of Khyrabad. This fault appears to be a compound fracture made up of many breaks, and enclosing within a mile southwards from Ainwa a little of the "red salt-marl" containing some rock-salt. The lower part of the greyer sandstones westward of this fault is much contorted, and contains bands of conglomerate in which limestone-pebbles full of nummulites occur.

Nummulites in limestone-pebbles of tertiary conglomerate.

Further southward along the run of the fault is a high mound of the drab gypseous clay previously noticed, appearing reddish near its base; and yet further on, near the mouth of the Súmbla-ki-Vándi valley, the fault seems to include a broken brecciated mass of the nummulitic limestone, forming a small hill.

Just near this place, towards the plains, are some small exposures of the gypseous salt-marl containing rock-salt and associated with reddish sandstones, like those of group No. 5, and dark conglomeratic shale or clay with the usual metamorphic pebbles. Here the earthy matrix of

the pebbles weathers and breaks up very much as an earthy trap-rock might do. These older rocks are faulted on one side against tertiary sandstones, &c., and on the other against low, reef-like, brecciated masses of the nummulitic limestones bordering the plains. Northwards of this faulted area the low ground is edged for a mile or so by the tertiary sandstones and red or reddish clays, but beyond this distance the road into Mári leads through a defile, on the eastern side of which are high cliffs of the same sándstones, &c.; while on the west is a narrow, broken, ridgy mass, a mile and a half in length, of the lower nodular nummulitic limestone with some of the jurassic beds. These rocks are strangely smashed and wedged on their eastern side among the tertiary sandstones and clays; they are bordered by a stony low bank of debris towards the plains to the west, while they abruptly terminate to the north against the salt-hill of Mári, with the intervention at either end of the line of junction of small fragmentary portions of the tertiary sandstone group.

Salt-hill, Mári.

The Mári salt-hill is an isolated mass of red rock-salt and gypseous marl, having an area of somewhat more than half a square mile, and rising from the left (or south) bank of the Indus to a height estimated at between 500 and 600 (more nearly 540) feet. All round the hill, salt and gypsum are seen at intervals in the marl, the stratification of which is extremely obscure, but indicated here and there by certain hard flaggy or thin-bedded dolomitic zones with dark shaly partings, these being nearly always highly contorted and impossible to trace for more than a few yards. In the harder of these bands, cavities are sometimes seen, perhaps formerly occupied by cubical salt-crystals, or crystals of pyrites; and sometimes the beds contain black, apparently carbonaceous, markings. These flaggy zones are generally associated with gypsum layers and sometimes with beds of salt, but they appear more frequently below than above the salt-beds. They are often several feet or in places even a few yards in thickness. The salt-beds vary considerably, up to 20 feet; they are of the usual red or white salt, and in many exposures seemed to be earthy

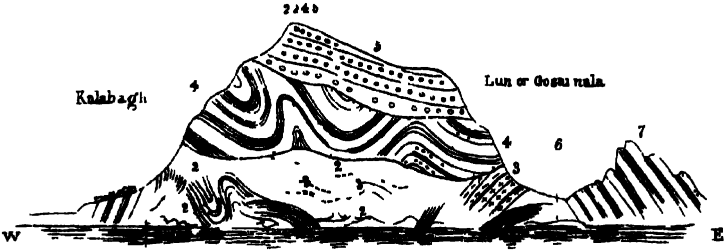
or impure (*Kalar*). On all sides of the hill the stratification, where seen, appears to be greatly crushed and folded; besides which, slipping of the rocks has evidently taken place frequently, so that it is impossible to be certain whether the greater part of the hill is formed of salt and gypsum, or whether contortion and slippage have not multiplied the appearance of one large and important group of salt-beds. At the time the place was visited no salt-mines were open, but there was abundant evidence of old workings and an enormous quantity of the mineral showing at every side of the hill. The atmospheric waste of the salt, and consequent displacement and confusion along the outcrop, make many parts of the ground not alone difficult to understand, but frequently inaccessible. (See fig. 53, Plate XXX.)

Quartz crystals.

At many places on the hill, but by report in some more than in others, the gypsum contains numbers of small bi-pyramidal crystals of transparent or slightly reddish quartz, frequently of great beauty and regularity. They are sometimes known by the name of Mári diamonds, and are used for ornamental purposes by the natives. The quantity of these must be enormous, to judge from the extent of ground at the foot of the hill which glitters with reflected light from their facets. Near the summit of the hill, and lower down on the Mári side, are some old Buddhist temples in ruins, having a more than usually antiquated appearance in consequence of being built of blocks of calcareous tufa, which occurs *in situ* not far off, and which probably hardened on exposure to the atmosphere; otherwise its durability would appear strange. On the opposite bank of the Indus beneath this hill the continuation of the salt-marl may be seen at the base

Kálabágh bank of the Indus.

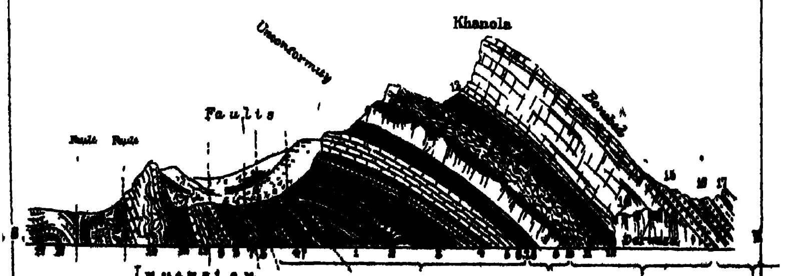
of a much higher elevation, and the thin flaggy and shaly zone, vertical and greatly twisted on the Mári bank, as far as it can be followed by the eye on the other side of the river, seems to form an open, contorted, synclinal bend, beneath a thick but broken band of salt, partly concealed and not continuous. Immediately overlying this salt and its associated marl are soft, greenish-grey and orange, sandy and clayey tertiary beds, thrown into bold



1 Grey dolomitic layers 2 Red Marl 3 Rock Salt 4 Tertiary Sandstones, Orange Series
5 Conglomerate (Siwalik?) 6 Concealed fault 7 Dangote & intervening Tertiary beds

Fig 54 Rough Sketch of Kalabagh Side of Indus Gorge & mountain above

Fig 55. Sketch Section in the Chichali Pass.



curves, cut off above by a line inclined to the east, coinciding with the base of a thick unconformable capping of coarse conglomerate, chiefly composed of limestone pebbles. (See fig. 54, Plate XXXI.)

Stratification of marl.

The sketch, fig. 53, Plate. XXX, will serve to show how little stratification generally appears in the marl, and how strongly this shows itself when the thin-bedded dolomitic bands and shales are present. The nearly horizontal beds, to the left over the salt-chowki, within a short distance further on in that direction, become vertical and bent backwards upon themselves, as may be seen at the edge of the Indus, where the vertical layers are cut across by a horizontal plane. In places along this bank of that river, large quantities of air or gas bubble up from under water, and a portion of the sandy, hard, river-bed, when the water has retreated, sounds hollow beneath the feet of men or horses, as if salt had been dissolved and removed from below.

Plains side of the salt-hill

The ground along the edge of the plains just outside the salt-hill and the limestone ridge near it is formed of regularly stratified red and green sandy alluvium, or debris, perhaps taking its colours from the preponderance of the same tints in the neighbouring tertiary sandstones, &c. The latter beds rise above the side of the little valley of Mári, opposite to the salt-hill, and indeed approach this hill within a few yards in some places.

Up the Indus.

Ascending the River Indus from Mári, orange and brown clays and grey sandstones, some of which are very thickly bedded, alternate repeatedly, dipping to the east-by-north at 45°. About two miles up the stream the rocks are seen to be faulted; sandstone beds, alternating with redder clays, coming against those with the brown or orange clays between. Further on near Dangot (called Dundhôt) cliffs, thick sandstones weather into cavities, and the cliffs are formed of extremely thick-bedded grey sandstone, a few pebbles occurring in thinner beds below. What could be seen of this magnificent cliff, nearly 2,000 feet in height, appeared to consist entirely of

sandstone beds without any bands of clay. Clay bands occur again between the sandstones further up stream, and within the next couple of miles two or three other faults occur, one of which lies in the bed of the river. Beyond this the stratification undulates at more gentle angles, and the cliffs are capped here and there by the debris of conglomerates formed of crystalline pebbles, among which grey syenite is most abundant; but the conglomerates themselves do not occur in the river until near the town of Makad.

Gold.

In the bed of the Indus, within a mile or so below Kálabágh, gold is washed. At one spot, pointed out by the Malik of this place, the bank in which it was sought was at some distance out in the stream, and the material to be washed was taken from a coarse sandy layer mixed with large pebbles. The gold-washers were not at work, but their *troons* (or cradles) and a few other rude implements were lying on the bank. The success attending the washing was said (as usual) to be very various, and when great a man might obtain from three to four annas a day.

Neighbourhood of Mári.

The entire neighbourhood of this village of Mári is most peculiar, the very lowest and some of the highest rocks of the range being here brought into contact. Dr. Fleming (report, page 252) at one place saw some tertiary strata dipping as if they would pass beneath the salt-marl; but the general arrangement is different. The strong escarpment of the tertiary sandstones faces the salt-hill, but the dip is in the opposite direction. These tertiary beds within the Mári valley frequently strike towards the hill, but without showing any inclination to underlie it.

That the main features of the present arrangement of the rocks here are the result of violent dislocation, rather than the tranquil change of conditions marked by unconformity, appears to be proved by the occurrence of some fragmentary portions of older groups than the tertiary sandstones, in close proximity, evidently parts of once larger developments of these rocks, which existed in their proper places

before the dislocation occurred. Though this is the case at Mári, on the opposite side of the river the salt-beds and red marl are directly overlaid by decidedly unconformable tertiary sandstones and clays, in a way which is difficult to explain by land-slip only; and it is equally difficult to imagine the thick nummulitic, the jurassic, triassic, carboniferous and "speckled sandstone" groups all to have died out naturally at one spot, while they are each represented at distances of from two to eight miles Cis-Indus, and some of them occur again in the neighbouring country Trans-Indus.

It is also as hard to suppose that such a thickness of these beds can have been removed by denudation from one small tract, while the softest of the whole series—the red marl, &c.—had stability enough to resist that agency.

The presence here of the great river Indus might do something to explain the peculiarities of the place so far as the upper (possibly fresh water or lacustrine) deposits are concerned, for an original line of water-discharge and *removal of material* might have existed here at a remote tertiary period; but any influence this could have had with regard to the disposition of the strata could not have obtained during the deep-sea deposition of the nummulitic period, or during the older marine conditions of the jurassic, triassic, or carboniferous times; so that there is nothing left to be supposed but that there was here dislocation so intense that the traces of the exact or progressive manner in which the results were effected have been destroyed.*

* If the salt-rocks of this locality could be looked upon as a newer deposit belonging to the tertiary period, the general relations might be more readily understood; but against this there is their identity, in most characteristics, with the salt-rocks of other parts of the range, and their association at no great distance on both sides of the river with other rocks of the Salt Range series, while the apparently newer salt beds to the northward differ decidedly in colour and association from those of this locality.

XIII.—Appendix: Trans-Indus Hills.

Geology of country Trans-Indus.

Although the Júd or Cis-Indus Salt Range terminates at the Mári bank of the river, it may be briefly mentioned that, in the mountains on the other side of the Indus, the geological structure is very similar to that of the western part of the Salt Range. The southern escarpment of the latter continues in a more strongly pronounced form, but no longer always presented to the southwards. The cliffs are still contrasted with more gentle slopes in the opposite direction, and these slopes, instead of sinking into an open plateau, like the Potwár country north of the Salt Range, face a mass of hills, some of which are lofty, and all towards the Indus possess a rather defined east-and-west arrangement. These hills are not distant from the Trans-Indus continuation of the Salt Range, and approach it so nearly as to coalesce in the vicinity of Kálabágh; but further west they are separated by the whole of the wide valley on the further side of which Bannu is situated.

Near Kálabágh.

At a little distance from Kálabágh the geology of the Trans-Indus regions presents some new features, the principal of which are—a larger development of the nummulitic and jurassic rocks, the latter being now more calcareous, and the intercalation of a distinctly cretaceous band between these groups a few miles to the westward. There are also among the newer formations some apparent unconformities unknown or, if present, concealed in the Salt Range proper.

Disturbance can hardly be called a new feature, yet its intensity appears to be even greater beyond the Indus, and the succession is so much broken that, in the small part of the ground as yet examined, incomplete sections only could be found.

Unfortunately when the officers of the Geological Survey visited Mári or Kálabágh, at three different and considerably separated periods,

severe sickness prostrated them, and limited their labors until it was found necessary to leave the place. During one of these visits, however, Dr. Waagen, with difficulty, made his way to the mountains north-east of Kálabágh and noted the following succession*:—

Section.

NUMMULITIC	Nummulitic limestone (part of)	50 to 60 feet.
	Soft grey marl	20 „
	Thin-bedded marly limestone	15 „
	Ashy grey calcareous marl with numerous *Conoclypeus*	20 to 30 „
	Alum-shale, inferior quality, with a little coal and many fossils	20 to 30 „
	Yellow nodular limestone irregularly bedded: many *Nummulites*	10 „
	Alum shale with *Nummulites* (many pits, but only a few beds workable)	50 „
	Hæmatite	10 „
CRETACEOUS	Dark grey glauconitic sandstone with *Belemnites*, badly seen	10 „

UNCONFORMITY.

JURASSIC	Grey clay with gypsum in thin beds, numerous canaliculate *Belemnites* and *Pleurotomaria*	6 to 10 „
	Yellow marly limestone, numerous *Mytili* and other bivalves	20 „
	Ashy grey nodular marls	6 „
	White hard splintery limestones	10 „
	Yellow thin limestone with *Pecten* and indistinct *Myacites*	50 „
	Variegated sandy clays	10 „
	Sandstone and limestone in alternating layers ...	30 „
	Soft yellow sandstone with whole beds of fossils; *Nerinæa*, *Cerithium* and bivalves	50 „
	Variegated sandstones and shales with thin coaly layers and alum-shales on three horizons	300 „

* Portions of this section are three times repeated by faults and contortions. Besides the unconformity and irregularity it shows, there is also the unconformity of the tertiary sandstones upon some of the above beds in other places, and upon the salt-marl on the right bank of the river at Kálabágh.

Lún (or salt) nala.

Along the Lún nala (or 'Drung Gorge' of Dr. Warth's report, and Gossai nala of Dr. Jameson) which comes from the north-by-west behind the Kálabágh hills, down to the Indus opposite Mári, the salt of this locality has been traced for a distance of about two miles from the Indus, and is reported to occur again nine miles up the valley. The salt is being worked at daylight in open quarries or small drifts, and was observed to dip at angles of 40° and even higher towards the westward. From Dr. Warth's report it appears that the worked seams vary from 4 to 10 or 20 feet, and that there are generally three alternations of good and bad salt, some of the working-places having been abandoned on account of the crystalline nature of the mineral. This crystalline salt was, however, being extensively raised when I visited the place, many beautifully transparent cubes, of several inches on the side, being observed in the heaps awaiting shipment across the river to Mári. As to the salt nine miles up the glen, if it exists, it is as yet unknown whether it may not belong to the saline series of the Kohat district rather than to that of the Salt Range.

A great fault is believed to exist crossing the River Indus and extending up this Lún valley, letting in masses of the carboniferous limestone and other rocks along its course, and also extending some way into the Mári glen; but as this fault traverses in the low ground, its exact place is concealed. The reason for inferring the existence of this fault is, that there is not room for the Salt Range series to intervene between the red salt-marl and the tertiary sandstones seen on opposite sides of the Lún glen, the discordant strata belonging to the latter series, occurring on the hill to the west, being apparently newer than the tertiary beds on the east side of the valley, and being themselves capped by a mass of very recent tertiary or post-tertiary conglomerate. The coal of Kálabágh is mainly jurassic, but thin coaly strings occur also in the nummulitic alum-shales. That from the jurassic beds continued till lately to be raised and sold in small quantities for the use of the river steamers. The alum is obtained from the black shales near the base of the nummulitic rocks.

Chichâli Pass.

At a distance of about nine miles to the westward of Kálabágh, the southern escarpment of the continuation of the Salt Range is intersected in a north and south direction by the fine gorge of the Chichâli Pass, at one part of which, where it crosses the nummulitic limestone (called the '*Darwáza*,' or gateway, by the natives), the shallow stream finds its way over a bed of flat sand between vertical rocky walls 250 or 300 feet high, and only 14 feet 6 inches apart at the narrowest place.

In this gorge near its mouth there is a good section exposed, showing extraordinary disturbance, and to a certain extent inversion of the strata (see sketch section, Fig. 55, Pl. XXXI). At the entrance, crushed, contorted, and faulted beds of the purplish-grey tertiary sandstones and dark-brownish red clays (Nos. 16 and 17) are seen, and the passage into the glen lies between vertical masses of the nummulitic limestone (No. 14) occupying a space of 150 yards across; parts of this limestone show the most intense crushing and compression within the mass. Black, flaggy, and olive-weathering alum-shales (No. 12), containing limestone-nodules, and nearly vertical, are next met with; then another mass of nummulitic limestone (No. 11), the strata of which, inclining at a high angle to the north, are faulted against some reddish-purple cretaceous sandstones (No. 9), with carbonaceous patches. These are inverted so as to dip steeply underneath dark-greenish olive sandy clays with *Gryphæa* and non-canaliculate *Belemnites* (No. 8), associated with which are some greenish sandstones with *Ammonites* and *Belemnites*, apparently underlying and passing into black alum-shales (No. 7) with canaliculate *Belemnites*. These, by reason of a reversed, crooked, angular, fault, partly underlie thin-bedded jurassic limestones (No. 5), with *Pectens*, &c., and these beds are again obliquely faulted and brought beneath more thin-bedded impure jurassic limestones and dark shales, red clays, and white sandstones (No. 4?) containing a few fossils such as *Gervillia*. Another fault, yet more oblique than the last, nearly coincides with the axis of an inverted anticlinal fold

in the adjoining beds, which are the lowest of the whole section, but still jurassic.*

Above this point in the glen, the section is regular without inversion, and the following is the description of the series arranged in natural order, the thickness given being partly estimated and partly measured or calculated :—

TERTIARY SAND-STONES, &c. ...	Red clays (17) and grey and greenish tertiary sandstones (16), with some beds of pseudo-conglomerate (15) containing bone fragments	Very thick.
NUMMULITIC ...	14. Strong compact light-grey nummulitic cliff-limestone of the *darwáza*	500 feet.
	13. Nummulitic marls and (12) dark shales ...	? 150 „
	11. Lower nummulitic lumpy limestone ...	150 to 200 „
	10. Alum-shales resting parallel on an eroded surface of the beds below . ..	30 to 40 „
	SLIGHT UNCONFORMITY.	
CRETACEOUS (NEOCOMIAN) ...	9. Strong light-coloured sandstone eroded at top, lower third black	60 „
	7. Dark, blackish-green, sandy and shaly bed, tough inside, passing down into	
JURASSIC ...	6. Dark olive sandstone and clay with Oolitic patches (equivalent to upper band of golden oolite ?) contain *Rhynchonella*, large planulate *Ammonites*, *Belemnites*, &c.	187 „
	5. Splintery hard, white limestones	180 „
	Shale band	400 „
	4 Calcareous shaly and sandy beds and yellow limestone	
	Grey limestone	
	Brown marly limestone	
	3. Shales with thin sandstones; a two-feet bed containing fucoids :—sulphuretted hydrogen spring	
	Hard sandy limestone and shales, *Rhynchonella* and fish teeth.	
	2. Lower golden oolite, variegated sandstone and thin coaly shales.	
	1. Grey and blue thin limestone and grey shales.	

* A quantity of carboniferous limestone is shown at this point in Dr. Fleming's section. None, however, as he observes, occurs in the glen; nor do the triassic beds appear.

The lower part of the cretaceous band and the upper part of the jurassic seem to form one thick bed of 187 feet, the *Ammonites* and *Belemnites* from the upper part having a neocomian character, while those from the lower part of the zone are jurassic.* Two chief bands of alum-shales occur, one above and the other below the lower lumpy nummulitic limestone; and there are other less distinct bands besides, in the lower variegated part of the jurassic series, near No. 8 in the section.

Alum is manufactured from the lower nummulitic bed at a village within the mouth of the glen.

SUMMARY.

Having now described, with some attention to details, the various local relations of the rocks along the Salt Range, a few brief general observations may be added with a view to conveying a comprehensive idea of the series as a whole.

Notwithstanding that the Salt Range geology is peculiar and differs greatly from that of neighbouring countries, so far as they are known, and that the series comprises various consecutive palæozoic, mesozoic, and tertiary formations, and even includes among the older rocks a group of silurian age, there is a remarkable degree of continuity preserved throughout the deposits. Though many pages of the record are doubtless missing, the succession is absolutely more continuous and complete than in many other parts of India itself, or in many equal areas of distant countries; and further there are indications that throughout the long lapse of time during which the successive stages of the series were formed, some very similar conditions obtained, resulting in the reproduction of the same kinds of rock. Thus, so far back as the formation of the group

Conglomerates.

next succeeding to the salt-marl in the western part of the district, abrasion of old metamorphic rocks and transport of their detritus to this region must have been

* From Dr. Waagen's field determinations while we were examining the glen together.

taking place, an action which was continuous or repeated through all except the more highly calcareous formations. Conglomerate or conglomeratic bands of similar metamorphic blocks and pebbles are found largely in group No. 2, or in its place; in less quantity, in the silurian band No. 3, and in No. 4; frequently in No. 5; in one place in the triassic No. 7; in another in No. 8; occasionally in the jurassic No. 9; again largely in the eastern portion of No. 10 (cretaceous?); while in parts of the tertiary beds No. 12, crystalline pebbles, of different aspect collectively, and probably derived from different sources, occur on several horizons and form very massive bands in some of the upper Siwálik beds.

Coal and coaly beds.

Again, the conditions necessary to the production of coal and carbonaceous rock have not been confined to one group of the series, such bands being met with in the gypsum with the salt-marl of Khewra; in rocks but a short way above it, mentioned in Section XI; in the upper part of the speckled sandstone and lavender clays No. 5 at Nursingphoár; in the carboniferous, jurassic, and cretaceous formations; and so largely as to form coal-beds in the nummulitic group.

Lavender clays.

Certain varieties of lavender-coloured argillaceous rock, generally yielding rapidly to the atmosphere, are also distributed. They occur in the salt-marl, associated with its layers of volcanic rock; in many places and with a very similar aspect in the "speckled sandstone series," notably at its upper limits; in the carboniferous limestone group, in the glen of Nursingphoár; in the probably cretaceous beds of the Bhál branch of the Nilawán ravine; and associated with the hæmatitic or lateritic band frequently but not always present at the base of the nummulitic group.

Hæmatite.

Nor are hæmatitic bands confined to one horizon. They prevail in the situation just mentioned (below the nummulitic), but occur also frequently in the supposed cretaceous rocks, more rarely in those of jurassic age, and in other situations.

A circumstance which is not peculiar to the Salt Range alone may be mentioned in connection with these hæmatites, namely, that they appear to mark places where some cessation or interruption of deposition took place. For instance, although there is no unconformity strong enough to be conspicuous at the base of the nummulitic formation, the probably cretaceous rocks beneath are but feebly represented; and if the presence of the lateritic hæmatite is indirectly connected with the want of cretaceous deposits, the occurrence of a hæmatitic band here and there in these rocks and in the lower groups may represent a greater development of strata on the same horizons in other places. At all events, where some slight appearance of discordance, hardly amounting to unconformity, occurs, between the carboniferous and the succeeding (cretaceous?) formation at Nursingphoár, and again at the top of the carboniferous beds near Kutta, hæmatite in the first instance, and with a little white sandstone beneath in the second, is the rock immediately supervening.

Salt and Gypsum.

Salt is characteristic of the lowest group, but traces of saline materials in the form of efflorescences are to be found in places in every succeeding zone (except perhaps the strong limestone bands), and in the newest formation of the whole series the sandstones and marls of the tertiary rocks are sometimes sufficiently saline to impregnate the water of the streams. Gypsum, too, occurs in the clays of group No. 5, in those of the trias, and in some quantity in the nummulitic coaly band. The presence of lime and magnesia dates back to the time of the red salt-marl, and the same substances are found again in group No. 4, the magnesian sandstone series; but calcareous and magnesian rocks prevail most largely in the carboniferous, western trias, western jurassic and tertiary (nummulitic) formations. The hard silicious, and aluminous rocks of most palæozoic formations are but poorly represented, slates and such common accessories as quartz veins being here entirely unknown, notwithstanding the pressure and disturbance which the strata have in many places suffered.

Lime and Magnesia.

Igneous rocks.

The absence of igneous rocks, too, with the exception of the volcanic-looking varieties occurring in a few places to the eastward, though unusual in such disturbed palæozoic rocks, may be very possibly connected with the continuously tranquil deposition shown by the general parallel conformity of the strata.

Early conditions.

From what has been already said, it will be seen that there is considerable difficulty in conjecturing under what circumstances the salt-marl was accumulated. For the stratified portion and its associated layers, however, estuarine or lacustrine conditions may have prevailed. The succeeding purple sandstone group contains no organisms to indicate its orgin, which, nevertheless, may have been marine. The next group contains a few marine (silurian) fossils. The "magnesian arenaceous group" and the "speckled sandstone group" may also have been deposited in sea water, subject to land floods, bringing down earthy matter. The carboniferous group and western portion of the trias are certainly marine, while the beds supposed to form an eastern representative of the latter group may have been deposited in an isolated tract of saline or of salt water. The jurassic, cretaceous, and nummulitic groups were also marine, or largely so, some plant beds in the first and the leaf-bed at the base of the latter, together with those bands in which coal or coaly shales predominate, being by no means necessarily exceptions; and the great mass of tertiary sandstones and clays have furnished nothing to contravene the supposition that, notwithstanding their great thickness, they were deposited under fresh or brackish water conditions.

Résumé.

The Salt Range rocks then form a continuous series, embracing alternations of calcareous, earthy, and arenaceous deposits, chiefly marine, but possibly in part of fresh-water origin—a series (including the more recent beds) comprising thirteen main divisions, of which nine are distinctly referable, each to one of the thirteen principal formations known to geology; and the ages of four are less accurately ascertained. Two of the latter are as

old as silurian, if not older, and two others, if not of this age, or carboniferous, must be intermediate.

From the top downwards, seven of these thirteen groups are synchronous with the five newest systems of the geological scale; the permian is not represented, but the carboniferous is largely developed in comparison with some of the others. Of the two groups immediately beneath the carboniferous formation, there is no reason why either should be called devonian or "old red sandstone." The lowest, however, appears to have a close relation, in some parts of the range, with the silurian zone beneath; and of the remaining two, nothing can be said as to whether one or both may be silurian or older.

Relations to neighbouring geology.

Of this series, there are no close petrographic representatives known in the neighbouring parts of the Punjáb hitherto inspected, if we except the tertiary sandstones and clays. The nummulitic limestones differ considerably from the large development of these rocks to the north. The cretaceous beds are different, both in character and fossils, from others met with, as are also the jurassic rocks; the mixed and variegated arenaceous, argillaceous, and calcareous group of the Salt Range bears no similarity to the Spiti-shales of the mountains on the outskirts of the north-west Himalaya. The triassic rocks with their abundance of *Ceratites* are also different from the strong limestone series of the latter region; and the underlying groups have no representatives around, so far as known, until the countries of Kashmir and Spiti are reached.* In the former, the carboniferous rocks have yielded to Captain Godwin-Austen some half a dozen or eight fossil species, known already to occur in this formation in the Salt Range; and from Dr. Stoliczka's Memoir on the North-Western

* The resemblance of the purple sandstone group to some old sandstones below, or in, the trias near Abbottabad, is much too slight to rely upon as any proof of their identity; and the carboniferous rocks mentioned as occurring near Abbottabad, in Dr. Verchere's paper, previously quoted, have no existence. See Memoirs of the Geological Survey of India, Vol. IX, part 2.

Himalaya it appears that four carboniferous forms are common to the formation as known there and in this Salt Range district.* When the Survey collections made in this country have been examined, it is possible that not only the carboniferous, but also the newer formations, may be found to contain other Himalayan forms.

The development of the whole Salt Range series is not at any place complete, the groups changing along their outcrop, in thickness, if not also in character; and the same series, from the fourth to the seventh group (in ascending order), or omitting the eighth, from the fourth to the ninth, extends westwards, Trans-Indus. The tenth group does not extend recognisably to the west; the eleventh covers all below it, except in the extreme east or west; and the twelfth (or part of it) is superimposed throughout. The latter group includes some representatives of the "Sub-Himalayan" divisions of Mr. Medlicott's Memoir "On the country between the Ganges and the Rávi;" but it is doutbful whether the Subáthu rocks northward and eastward of the Potwár plateau are represented to any extent along the range except by a few thin layers in its eastern sections. Even though some similarity in the Bakrála ridge has been pointed out, the close identity of the lower tertiary Salt Range sandstones with the Náhan group is not at present strongly insisted upon, while there is sufficient reason to suggest it. The Siwálik beds above these have been lately shown to belong to the same group both here and in the country extending hence to the Sub-Himalayan area.

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* Captain Godwin-Austen's specimens, similar to those of the Salt Range, are *Athyris subtilita*, *Spirifera Moosakhailensis*, *Rhynconella pleurodon*, *Streptorhynchus crenistria*, *Productus semireticulatus*, and *P. Humboldtii* (See Mr. T. Davidson's list in Part I of this Report; and Note on the carboniferous Brachiopods collected by Captain Godwin-Austen in Kashmir, by Mr. Davidson, Quar. Jour. Geol. Soc. Lond., Vol. XXII, p. 39).

Dr. Stoliczka's specimens, identical with Salt Range ones, are *Spirifera Moosakhailensis*, *Productus longispinus*, *P. semireticulatus*, *P. Purdoni*.—Memoirs, Geol. Survey of India, Vol. V, Part 1, page 27.

Economic Resources.

The economic resources of the Salt Range are numerous and varied; several of them are of minor importance, but one, the rock-salt, for which it is famous, occurs in a quantity and possesses a value which may be called incalculable. These salt-deposits, together with those of other parts of the Punjáb, are some of the largest and purest in the world, yet their origin is equally with others involved in obscurity.

In Mr. Baden, Powell's "Economic Products of the Punjáb," all the mineral economic resources of the Salt Range and its neighbourhood are alluded to, though the references are to be found amongst matter relating to building materials, salt, &c., from other places as well. A passage given as an extract from this work,* in the preliminary copies of the Punjáb Gazetteer, mentions the following minerals as occurring in the range: "salt, coal, sulphur, petroleum, ... copper, gold, lead, and iron, the latter as rich hæmatite very abundant in some parts, to such an extent that the rocks containing it prevent by their attraction the indications of the magnetic compass." This passage gives a very exaggerated idea of the products of the range. The coal of the Salt Range is not great in quantity; it is poor in places and pyritous and shaly, besides being difficult to work. The sulphur occurs in the smallest quantities, native and otherwise. The petroleum is likewise very limited indeed, as may be gathered from the several reports on the subject by Mr. Lyman (see List of Authors). The copper mentioned at page 9 of Mr. Powell's work is quite inconsiderable. The stream-gold yields but a scanty return for much labour. The lead (pages 11 and 12) occurs only as small disseminated crystals of galena in the peculiar dolomitic rock of Karangli Hill. The iron, so far as I am aware, occurs generally as common hæmatite, forming inconstant

* Gazetteer of Jhelum District; Geographical and Physical Section, Geology of the Salt Range. Extract from Mr. Baden-Powell's "Economic Products of the Punjáb," pp. 131-135; end of extract, p. 15.

layers, often so earthy as to resemble laterite, and I never found it affect the magnetic needle of my compass.

In his introductory chapter (foot-note, p. xii, and again at p. 8, para. 33) Mr. Powell mentions a new discovery of a first-class iron-ore in hills belonging to the Salt Range, made by Dr. Henderson, Civil Surgeon of Shahpur, who had procured from it bars of the metal. This ore was obtained from the Korána (Kot Keràna) hills, previously mentioned, not from the Salt Range itself. "The ore was very abundant in several of the hills, and attempts to work it appeared to have been made." Dr. Henderson believes it to contain at least 70 per cent. of iron, which was favourably reported upon by Mr. Bocquet, of the Punjab Railway, and Mr. Harrison. Dr. Henderson only smelted a few maunds of the iron, with a primitive apparatus, as fuel was scarce in the vicinity, and he estimated the cost of production at Rs. 7 per cwt.*

SALT.

Salt.

The places of the occurrence of the salt, its composition, position, and general relations, have been noticed in the preceding pages, and reference has been made to the memorandum by Dr. Oldham, to the reports of Dr. Fleming, to the full report of Dr. Warth (the latest published), and those on the administration of the Inland Customs Department, in all of which much detailed information may be found.

Where so much has been already written, it seems superfluous to add further remarks upon the salt-mines of the range; some general idea of them may, however, be briefly conveyed, rather than that they should be left altogether unnoticed; mining details are taken from Dr. Warth's reports.

It appears that the mines were formerly much more numerous, and under native management merely consisted of small openings at first,

* Information kindly supplied by Dr. Henderson, under date Ráwalpindi, September 10th, 1877.

afterwards unsystematically enlarged, until they became dangerous. Since the annexation of the Punjáb, it has been found useful for facility of collecting the revenue. to lessen their number greatly; and still further reduction has been proposed or lately carried out.

The mines open during the progress of the Survey were those of Khewra, Sardi, and Varcha on this side of the Indus, and the open quarries of Kálabágh beyond that river. Besides these, an experimental driving was being sunk (and is intended to be carried on from time to time) beneath the southern cliffs of Mount Tilla, in order to prove the existence or absence of workable salt within reach, that point being so much nearer than the others to the Northern State Railway—not yet completed, but in progress. Up to the latest information the salt had not been reached.

Mayo mines

The largest mines of the range are the Mayo mines at Khewra, so called to commemorate the visit of a late Viceroy. In these, vast but dangerous chambers had been left by the old Sikh workmen, who either knew or cared so little how or where they worked, that two heavy pillars supporting the roof of one excavation were left resting upon a thin crust of salt, spanning another large chamber below. It has been remarked that most of the roof-falls of the mines took place at night, and the miners, who work only in the day time, may have relied on this poor chance for safety. As it was a matter of great uncertainty how long these pillars would remain supported, instead of supporting the roof above, their removal was ordered, when suddenly on Sunday the 5th of June 1870 one of them broke through, carrying with it a large part of the roof, and forming a crater on the hill in which the mines are situated. The fallen mass of salt and marl was estimated (by Dr. Warth) at half a lakh of maunds, from which the damage that might have been done had there been miners at work beneath may be imagined.

The present state of these mines differs widely indeed from that which existed during the earlier visits of the Geological Survey Officers to the

place, and still more from the state of things described by Dr. Fleming and Mr. Theobald or previous writers. When I was going through them first with the Deputy Collector formerly in charge,* his kindly warnings not to remain in certain places were repeatedly given; but now, even though the mines are far from being everywhere safe, the alteration in them is so great that an air of security is derived from the regularity of the new works, and the business-like manner in which the operations are being carried on. Since Dr. Warth took charge, this great improvement has been effected, though improvements upon the old systemless plan of working were of course in progress ever since the British rule began, as evidenced by the very names of workings like "Thompson's drift," "Purdon's tunnel," "Matthew's drift," &c. Only a few years since, entrance to the mines was gained down a slippery incline or through an adit, but now one can drive in upon a tramway, through a spacious passage, and observe a system of regular pillars and openings, with various inclined and other drifts, leading to a main passage, through which the salt is taken out of the mine in trucks. In former days, the two principal mines here (the Baggi and Sujewál mines) were disconnected, and both of them ill ventilated: a passage has now been opened from one to the other, which not only gives a fine rush of air through the mine, but offers an additional means of escape for the numerous workmen in case of danger.

The old chambers, however, still remain to contrast with the new system, and when lighted up the effect of these great caverns is very picturesque, particularly under the influence of coloured lights or that from the magnesium lamp; but it is only in very strong lights that the brilliant reflections from the facets of crystals become at all prominent, though frequently spoken of by previous writers, before blasting powder was so much used; nor are stalactitic masses so common as one might expect.

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* The late Mr. Mathews.

The method of working in these Baggi and Sujewál mines is described by Dr. Warth in his first paper previously referred to, from which the following is condensed:—

The miners work in three different ways in the Baggi mine. First, forward from a certain floor into the rock salt. This is called the *katti* *(kuttee)*, and is the most troublesome. It is nearly as hard as cutting drifts, there being a good deal of pickwork before the men can blast. As the *katti* is carried forward, they gradually work the roof down, sitting upon tripods, some of which are 25 feet high. This is called *chhat* *(chutt*)* work. When they have advanced with the *katti* and *chhat*, they begin to work from behind downwards. This is called the *par* (*pur*), or deep working. This *par* ought to be very easy work, but it is not, because from want of space it cannot be carried on in regular advancing steps; instead of this, the miners work the *par* down directly over are as marked out to them, both in Baggi and Sujewál mines.†

Dr. Warth proposed to operate in a contrary manner, namely, to work the *katti* on the roof of the salt seam, and the remaining salt down to the bottom as *par* by steps. The improvements are being gradually carried out, and the appearance of the mine is yearly changing in consequence, so that in course of time there is little doubt the system will become as perfect as possible. Not very long ago, gunpowder was never used; now its advantages are fully felt, and Dr. Warth has fired some large blasts, separating hundreds of maunds of the salt at once with perfect safety.

From one of the smaller mines called Phurwalla, men, women, and children had carried full 40 lakhs of maunds of salt up a narrow steep and crooked drift, and from the whole Mayo mines Dr. Warth estimates the

* From the word pronounced "Chutt," meaning roof, or ceiling.

† The Khewra miners use the following names: Salt, *Loon*. Impure earthy salt, *Keller*. Crystallised salt, *Sheesha*. Red marl, *Lal mattee*. Cracks across the salt, *Ugge*. Red lines marking the stratification, *Purree*. Small salt, *Soor*. Waste salt in small pieces, *Malba*. Fallen salt used for sale, *Kanee*. Dangerous state of roof, *Chiddiler*. Drift, *Suan*. These are spelled here as they are pronounced.

gross amount of salt removed at 300 lakhs of maunds; but notwithstanding the length of time these mines have been extensively worked, and though each season adds a concentric belt to the excavated area, they show as yet no signs of becoming exhausted.*

In order to facilitate the cariage of the salt from the mines, Dr. Warth's tramway has been extended to the mouth of the gorge, and thence a wire-rope tramway has been constructed (under the superintendence of Lieutenant DeWolski, R.E.) to the village of Chak Nizám, on the southern bank of the Jhelum, above Pind-Dádan-Khán, and ten miles from the Khewra gorge. This has been for a few months completed and is occasionally in working order, but difficulties have had to be contended with in the unusual length of the line, and the effect of the water of the country upon the boilers of the engines that supply the motive power. When fairly at work, this tramway will be an important aid in the rapid distribution of the salt by means of the Northern State Railway.

The Sardi mines to the west (ten miles or so north-westward from Pind-Dádan-Khán) are smaller and less favourably situated for working, being sunk below the bottom of the glen instead of in a hill side like those of Khewra. They were more recently opened than the latter, and were originally constructed on a better plan, flights of steps being cut out of the salt, and the roofs supported. Owing to their low situation they have been at times stopped by access of water, and I believe they are now altogether closed.

The Varcha (or Wurcha) mine is in the hill on the right-hand side of the Varcha gorge, about thirty miles west-north-west from Shahpur. The mine is at a considerable elevation and is large, though only about 20 feet of salt are excavated out of a bed of much greater thickness,† the remainder of which is not sufficiently good for commercial purposes

* For very full descriptions of the mines, modes of working, outturn, etc., Dr. Warth's papers, noticed in Chapter I, may be referred to.

† Dr. Warth remarks that the salt mines of Cheshire are being excavated in the same thickness as the Varcha bed,—20 feet.

at the Salt Range. There are large remains of old Sikh workings and great natural shafts or vertical water-courses, a sketch of one of which has been given (see Pl. XXV). The old workers here, as elsewhere, left the roof unsupported, and it is falling in, but in the modern mine this is provided against. While the salt-bed continues to dip, as it at present does (30° to N. W.), no alternation in the mode of working (according to Dr. Warth) will be needed. The mine is well ventilated and clean, and has two modes of ingress, but no low-level water-escape.

The Kálabágh workings are all "at daylight," in a thick group of salt-beds, ranging from 4 to 10 or even 20 feet each. They run along the right side of the Lún or Gossai Nala (or Drung gorge), the salt being found to extend from the base of the hill as high up as 200 feet; but the beds are not all sufficiently good to be worked, 20 feet being the largest known thickness of a workable salt-bed here. All the beds dip west at nearly 70°. The salt outcrop extends for some two miles up the glen, and there are fourteen working places or quarries.*

Besides those mentioned there are numbers of old mines, about which nothing is known, while some that have been inspected were found to promise large supplies of salt. Several of the old mines occur in the Jutána and Kúsak beats, four in the Makrách beat, three in that of Malot; eight in Sardi beat, four in the Nilawán ravine, three in the hills about Músakhel, and several at Mári.

The old Jutána mines were being worked when Dr. Jameson visited the Salt Range in 1843, and had then been open twenty, thirty, and thirty-five years. The descent into the body of the mine was accomplished by steps cut in the salt, and the workings seem to have been large, but as irregular as usual in the Sikh excavations. The salt was removed in masses, two of which were a load for a camel; also in smaller pieces with which to load oxen. The miners were paid one anna per maund for extracting the salt, and this was sold for a rupee per pucka maund. The

* Dr. Warth's Report, already quoted.

price of a camel-load was Rs. 6 to 8, and before it reached Umballa, paying hire, duty, &c., it cost from 8 to 20 rupees.*

The best idea that can be given of the quantity of salt produced by the Salt Range mines will, perhaps, be obtained from the value according to the subjoined abstract of the receipts for four years (taken from the report on the administration of the Inland Customs Department for the official year 1870-71, page 14). The rate at which the salt is sold at the mines is Rs. 3-1 per maund† :—

Receipts from the Salt Range Mines.

YEARS.	NAMES OF MINES.				TOTALS.
	Mayo	Sardi.	Vurcha.	Kálabágh.	
	Rs.	Rs.	Rs.	Rs.	Rs.
1867-68	28,97,530	1,91,819	2,83,783	2,16,189	35,89,321
1868-69 ...	29,10,338	2,50,506	4,16,292	2,03,445	37,80,581
1869-70 .	35,03,171	4,26,485	3,99,856	1,61,946	44,91,458
1870-71 ...	27,99,092	2,20,686	4,45,040	1,99,584	36,64,402
				TOTAL ..	1,55,25,762

This total is equal to £1,552,576, or an annual average amounting to the large sum of £388,144.‡ It appears from the same report, page 15, that the average amount of salt cleared from the depots during the above years was 12,91,148 maunds.

With regard to the continuity of the salt-beds, the indications, so far as can be judged at present, point to the occurrence of several sets of beds, rather than the extension of any one group, and the quantity of salt, as now known or exposed, probably bears only a small proportion

* Dr. Jameson's Report quoted; see list of previous publications.

† Rs. 3-1=six shillings and one and a half pence. A maund is equal to 82 lbs.

‡ This is the average taken from the above figures; that given by Mr. Wright, the former local head of the Salt Department, is smaller by nearly £5,500, but he may have deducted some working expenses of the Department.

to that which is concealed or which may have been destroyed. Mines have been worked along the range from periods so remote that their date cannot be ascertained,* and very much of the salt has been both naturally and artificially removed, yet if the present outturn were increased many times, the supply might still be considered inexhaustible, so far as quantity is concerned. The salt-marl appears so frequently that its continuity, for a distance of 134 miles, more or less, can hardly be doubted, and it occupies a breadth which, on the same sort of evidence, may be fairly assumed at from four to five miles; while its reappearance on the north side of the range in two places would indicate its underlying the mountains everywhere, with a breadth of from twelve to sixteen miles, or it may extend to a much greater width. Allowing a breadth of five miles, this estimate† gives an area of salt-bearing marl 670 square miles in extent, in which the salt-zones vary from nearly 100 to 275 feet in thickness; separate beds or groups of beds of salt, where the size of the bands collectively is least known, having thicknesses of 20, 30, and 40 feet.

Supply.

Excepting for about twelve miles in length, at the eastern end of this area, salt is seen or known to exist within almost every mile where the marl is fairly exposed, so that although little or nothing is known as to the manner in which the salt-zones are laterally extended or terminated, the quantity of the mineral present must be enormous if it is considered that (a roughly shaped cubic foot of salt weighing about 136 pounds) the solid contents of a bed of salt, only 30 feet in thickness and one square mile in area, would amount to over 50,778,514 tons.

* "Dr. Fleming records that the mines were first worked in the reign of Akbar, and mention is made of them in the *Ain-Akbari*, but this is all the information existing upon the subject. The native tradition is that Akbar was informed of the existence of the salt by a certain Asp Khan on condition of his receiving, as a reward, during his life-time, a sum equal to the whole of the wages of the miners employed in digging it. Salt was sold in Lahore during the reign of Akbar at the rate of 6 annas per maund."—*Punjab Government Gazetteer, Jhelum District.*

† A smaller estimate was made previously in order to be well within the mark (see Chapter III, p. 81).

The detailed accounts of the mines given in publications already referred to being very copious, it has been sought to convey here a fair general impression of the deposits, rather than reiterate all the details previously published.

The new facts ascertained by the latest explorations are chiefly these:—

(1.) Where the workings have been most carefully surveyed, the salt has been found in zones, consisting of several distinct beds, within distances of about 600 feet, 200 feet, and less, of the top of the marl and gypsum.

(2.) That the arrangement and thickness of the beds, and the quantity of marl and gypsum (more or less intermixed) intervening between the salt-zones, and between the group superior to the marl and the salt itself, indicate more variability than sameness of the exact horizon upon which the salt is found.

(3.) That there seems to be a larger development of so-called bad salt in the western than in the eastern part of the district (which bad salt would, however, in other districts be extremely valuable).

(4.) The recent and most detailed explorations by the Salt Department have been chiefly confined to the old workings, and other beds of salt have not been sought for, except at Mount Tilla, where none has yet been found. Without regular prospecting operations it would be impossible to hope for information about the salt-rock in this or other directions, partly on account of the tendency which the marl has to conceal the enclosed salt; and whether the lower part of this "red marl" does or does not also contain valuable beds of salt is quite unknown.

Should it ever become necessary, the best place, perhaps, for ascertaining this would be the ground about Chambal hill (west) between the Jutána and Kúsak Beats.

Though the method of mining the salt is being improved, and arrangements for its transport by wire-tramway and rail from Khewra

are in progress, the old system of carriage still exists elsewhere, together with the waste this occasions. The salt is reduced to rough spherical lumps, to prevent the corners being rubbed off during its rough transport in open nettings or hair-cloth bags. So long as the merchants prefer, and can obtain, the salt in blocks, it does not seem likely that any steps will be taken to utilise the enormous quantity of valuable salt now wasted.

Coal.

Coal.

The coal of the Salt Range has formed one subject of a detailed report by Dr. Oldham in the memorandum on the mineral resources of the district, already noticed. It occurs at eighteen or twenty localities, including Kálabágh, but at only a very few of these in fairly workable quantity. The coal of the Salt Range proper generally comes from near the base of the nummulitic rocks, and is most largely developed at a short distance from Bhágauwála. It has been worked here, at Pid, and to the westward at Samundri, besides small quantities being raised at other places. The coal is not of bad quality in some places, but the amount of the best kind is very small and becomes deteriorated by mixture with the more sulphurous and shaly portions of the beds, so that the fuel obtained falls to pieces and it is liable to spontaneous combustion.

The Kálabágh coal or lignite is of jurassic age and of better quality than the former; it is composed of portions of trees in a fossilised state, not forming a bed, but distributed in both shales and sandstones, from the former of which the coal collected for sale has been obtained.

As to quantity, Dr. Oldham estimated that there might be raised at the Bhágauwála locality 16,20,000 maunds of coal, and at Kálabágh some 45,000 maunds. It appears from the mineral statistics by Dr. Oldham, in Vol. VII of the Memoirs of the Geological Survey, that

the following quantities of coal were raised at the Salt Range (the localities not being given) :—

In the year 1863	... ...	199	maunds.
" " 1864	... ...	9,742	"
" " 1865	... .	27,528	"
" " 1866	. ...	14,596	"
" " 1867	. ... ..	710	"
		52,775	maunds, or
		1,937	tons, 11 cwt.

In nearly all of the localities given in Dr. Oldham's list (see below), and in a few besides, the coal of the lower nummulitic beds was found to be so dull and weathered on its outcrop that it was only by cutting into the beds the mineral could be seen. In some spots the waste-heaps had spontaneously ignited, but this did not appear to have occurred in the beds. At no locality were works being carried on, and the largest of the abandoned excavations were those at Pid and Samundri, where bungalows had been built; that at the former place was occasionally used, but the house at the latter, to which there were but faint traces of a road, was fast falling into a ruinous state. It is supposed that these were the places whence the nineteen hundred and odd tons just mentioned were extracted.

Everything connected with these deposits of coal and shale which has been ascertained during the examination of the ground, tends to show that they have a very general but not continuous existence, and there are circumstances to the westward which show either the occurrence of a higher band of coaly shales, as at the Bakh ravine, or that, from increase of the lower portion of the nummulitic limestone, the place of the band has been shifted higher up in this group. Westwards of this place, the basal portion of the nummulitic beds is still earthy, and the form of the talus, at the foot of the cliffs in which the limestone terminates, shows the beds to be soft, the rocks next below the nummulitic group in this region, when seen, being often earthy and shaly. Some traces of gypseous clay, and the gypseous nature of the lowest

nummulitic beds at the Bakh ravine, as well as the occurrence of the hæmatitic zone near that place (and further westward), would indicate the continuance of the same characteristics at the base of this series.

In very many, or perhaps in most cases, the débris at the foot of the nummulitic limestone cliffs conceals everything just below it, but several sections, given in the foregoing pages, will show the local absence of these coaly shales, or else that their importance and coal-bearing character is locally diminished. The frequency of their occurrence and the larger development of the coal layers towards the eastern parts of the range, render it very probable that if it were ever worth while to institute trials, the coal would be found in many places now concealed over that country. The fact, however, should be borne in mind, that the soft shaly nature of the associated rocks and the occurrence of the hard nummulitic limestone, more or less nearly horizontally extended over the coal-bearing beds, would always present much difficulty in carrying on mining operations.

From Dr. Oldham's memorandum (being a report to Government) the following particulars are abstracted to supplement those already embodied in this Memoir :—

Bhaganwalla.—Extent of coal along outcrop, two miles; thickness, three feet six inches. Coal greatly cracked and jointed; when exposed to the atmosphere, disintegrates and falls to pieces. Crystals and flakes of gypsum common in fissures of coal, and iron pyrites, which, decomposing, gives rise to spontaneous ignition of the coal. Much care needed, if the place (or any of the Salt Range coal) be worked, to keep galleries quite clear of dust and small coal. Good masses of bright coal can be obtained from this place; to work which, successive galleries would be required, one over the other. Locality inaccessible, but improvable in this respect.

2. *Kyora* (*Khewra*).—Above the gorge, coal poor, full of iron pyrites, and with layers and irregular masses of clay interbedded. Thickness two feet eleven inches. Coal divided into two by a layer of shale.

3. *Pid.*—On side of hill facing the south. Dip to north, 60° or 64°: thickness of coal, three feet when pure. Good bright fuel; falls into fragments after exposure to the air. Not quite so much pyrites here as in other places. Locality close to a good road and easily accessible; probably a fair amount of good fuel here; a thick covering of debris prevents its being traced.

4. *Dandot* (No. 1).—Coal seen on edge of a fault or slip; coal two feet six inches; only a small fallen mass of rock and coal, useless as a permanent source of fuel.

5. *Dandot* (No. 2).—A mile further north, in a fallen under-cliff, thicknesses of two layers fifteen to eighteen inches and from ten to twelve inches. Beds squeezed out to south and cut off to north; fuel not bad; coal divided by a band of sandy shale.

6. *Dandot* (No. 3).—Further to the north and west, same general character; no greater prospect of successful exploration.

7. *Nila.*—Coal poor in quality, dip 30° to 35° to south-east; coal more than fifteen inches thick; eight feet of blackish shales below it with thin layers of flaky coal.

8. *Karuli.*—Coal slipped with the rocks on which the village is placed; useless as well as very limited in extent.

9. *Nurpur* (*Nilawan*) —Northern end of main gorge under high cliff, along which patrol road has been carried; little prospect of any successful working.

10. *Sowa Khan.*—On the edge of a slip fault, which has brought the nummulitic limestone into contact with the red and purple marly beds of the salt series. Section concealed to a great extent by debris; only a portion of the rocks, far removed from their natural position.

11. *Deiwal.*—A little patch of coal and coaly shale in one of the lower spurs of the hills a few miles from Deiwal village, but said to be within its boundaries, perfectly useless as a source of fuel. The coal occurs in a heap of debris of all kinds, only a few feet in length, and varies from an inch or two to nearly two feet in thickness.

12. *Katta.*—At the base of a large cliff of nummulitic limestone under the Chamil hill, near its base, both limestone and coal broken. No prospect of any continuous supply. The bed of no thickness.

13. *Chamil.*—Under the lofty scarp of the nummulitic limestone at the north-eastern corner of the line of cliffs which form the southern face of the Chamil plateau; coal and associated shales in their true position unfallen, dip 12° to north 5° west. Two coal seams, one from six inches to ten or twelve in thickness, the other fine jetty coal, six inches. Place not very difficult of access, but no workable quantity of coal.

14. *Sungle Wan.*—Or one mile west of village of Arar, close to Diliali hamlet, at level of water in bank of stream. Two thin seams, upper six inches, lower ten to twelve inches, dip south-east 30°. Beds a small patch under a large talus of debris; at foot of high scarps of limestone, one mass of broken debris. Same beds again seen not far off; much broken up; no prospect of being profitably worked.

15. *Amb* or *Umb.*—The Sulgi coal locality; coal of no value and no extent (see detailed descriptions foregoing).

16. *Kalabagh.*—Irregular strings and patches of coaly matter in the alum shales, especially in the lower group of the shales, not extracted. (This is not the place whence the Kalabagh coal is taken, the latter being jurassic; this is nummulitic.)

17. *Kotli.*—Southern end of the Chichali Pass, similar to the nummulitic locality of Kalabagh. Specimens of the coal have been analysed. It is for the most part rather difficult to ignite at first, throwing out a large quantity of dense smoke (in most cases with a

marked sulphurous odour), but when ignited it burns well with abundant flame; does not cake much, and, with ordinary care, yields but little clinker. Tried practically in the locomotives of the Punjab Railway, both at Lahore and Mooltan, it proved very successful; it was found to answer well, both in getting up and maintaining steam for an ordinary train travelling twenty-five miles per hour. It answered well at Mooltan, but required screening and foreign matter picked out. There was dust from its friable nature, and the fire-bars required attention. It was tried in the steamers on the Indus, and a favourable opinion of its quality was given, it having been calculated to be, weight for weight, four times as effective as wood.

"The coal would prove a very effective fuel, though it cannot be considered a first-rate coal, one maund of it being equal in effective work to 2·5 to 4 maunds of ordinary wood."

Petroleum.

Petroleum.

The position and circumstances of the petroleum and mineral tar situated in the western part of the range have been mentioned in the foregoing descriptions, and all but one locality have been fully reported upon by Mr. Lyman (see List of Authors). This is the Sulgi coal locality, where the rocks which contain the tar are only an isolated and widely separated mass of the tertiary beds, the exact continuation of which it would be impossible to point out. The quantity of the tar exuding here is not commercially valuable, but the saturated sandstone rock, if continuous beyond what can be seen at the surface, could easily be quarried.

The petroleum near Jába at the Chota and Burra Kutta glens comes to the surface in greater quantity than in most other places in the mineral oil region of the Upper Punjáb (the workings near Fatehjang of course excepted), the natural supply being about four and a half quarts a day.

The localities are in some respects well situated for boring, and the distance from the Indus at Kálabágh, where water-carriage could be had, is only about nine miles. A tolerable foot-road exists hence to the village of Jába, less than two miles from the springs. The oil is dark green, and the water which accompanies it evolves sulphuretted hydrogen.

The other localities produce such trifling quantities of petroleum as to be of little or no economic value.

BUILDING-STONES.

Building-stones.

The stones chiefly used for building along the range are the smooth fine-grained sandstones of the purple sandstone group. These dress well, but being often soft and sufficiently saline to take up moisture are not so good as some other rocks which are less easy to work. It is stated that these furnished the material used to raise the memorial obelisk on the battle-field of Chilianála (commonly called Chillianwalla).

A white sandstone, seen on the ascent from Pind-Dádan-Khán to Pid, just after leaving the plains, seemed likely to make a good and handsome building-stone. Many beds of the dolomitic sandstone group appeared also well fitted for use, though not likely to dress so well as the purple sandstones.

The limestones of the carboniferous and nummulitic groups, and, indeed, some of the more regularly bedded triassic or jurassic limestones, would furnish excellent building materials.

Putting aside the softer sandstones, and the more shaly or saline beds of any of the sub-divisions, there is hardly one group of rocks above the salt-marl in which durable and easily worked building-stone could not be found, and a mixture of the many different-coloured stones procurable would form handsome ashler walls. Blocks of large size could be obtained from many of the sandstones of the dolomitic group No. 4, or from the formations containing limestone. The group No. 8 furnishes good flags, some of which have been used in the new fortified barracks at Ráwalpindi. Lime can be obtained from one or other of the formations almost everywhere.

Although there is no scarcity of strong building-stone, the builders of the ancient Salt Range temples (probably Buddhist) generally disregarded all others in favour of the calcareous travertine found in many parts of the range. This, although brought from a distance, seems in some cases to have been preferred to any material nearer at hand. This

light and porous stone was probably easily cut while fresh, hardening to a certain extent on exposure. It is not, of course, calculated to retain fine sculpture or tracery, but it appears in exposed situations to have withstood the action of all weathers wonderfully well. The blocks are rough and often much decayed in places, but still they retain their positions in the body of the buildings, being, perhaps, more closely bound together by calcareous infiltrations. The material at best is liable to decay (less so, perhaps, in the Salt Range climate than elsewhere), and from its porous nature can oppose little resistance to crushing force; hence it would be unsuitable for large modern works.

Ornamental Stones.

Variegated limestone.

The variegated and banded concretionary limestone of the nummulitic rocks on the plateau above the head of Sardi glen has been a good deal quarried for ornamental purposes. Knife-handles of various kinds and paper-weights are made of it, and the church of Shahpur is said to be flagged with it. When polished, the curved laminæ of the stone are plainly seen; thin, purple, and yellowish or grey lines often simulating the structure of fossil wood. Some of this stone is also reported to have been used in the construction of the houses of wealthy natives along the southern face of the range and at a distance towards Lahore. The stone is also said to be found in one or two other places in the neighbourhood, but the exact localities could not be learned.

Hæmatite.

Another stone used much in the same way as the variegated limestone is a part of the hæmatitic band at the base of the nummulitic limestone; portions of this when polished exhibit red, greenish, and white markings which often resemble sections of amygdaloid.

Chert.

The chert or flints of the limestone-beds, particularly of the nummulitic limestone, are used as *chak-maks* to procure fire, and the Sikhs are reported to have made gun-flints from them.

Mári diamonds.

The bi-pyramidal quartz crystals either transparent, reddish, or more opaque, found in quantities in the gypsum of Mári salt-hill, are worked into necklaces by the natives, consequently those longer than usual or more regular are valued to some extent. The mine in which the best are said to occur was closed when Mári was visited. Dr. Jameson (Report, page 206) says they were also found in the rock-salt; but this has not been confirmed by any recent observations.

Salt.

Some of the opaque salt is often turned or cut into ornamental utensils.

Gypsum.

Gypsum.

The gypsum of the salt-marl exists in enormous quantities, and much smaller developments of the mineral are to be found among some of the other groups, chiefly as selenite in the shaly beds associated with the coal. It is, generally speaking, a pure sulphate of lime, and the only uses to which it is known to be applied are for mixing in a powdered state with mortar (as mentioned by Dr. Fleming); some of the more compact varieties near Sardi are turned to form plates or other rude ornamental utensils. Some use must, however, be made of the transparent variety, for it is reported to fetch Rs. 3-14 per maund at Lahore.

Lavender Clay.

Clay.

The lavender clay-ash or decomposed rock found with the volcanic rock of Nilawán, &c., is used by the natives as soap or to assist in washing.

Galena.

Galena.

A small quantity of galena, in little nests and crystals, is found disseminated through the dolomitic sandy rock of the escarpment at the top of Karangli hill. Here a sort of mine, some yards in length, leads out to the face of the

cliff, on which side it is inaccessible, and to enter it a descent of several feet has to be made by the help of a branching portion of a tree.

The galena, when collected, sells for Rs. 4 or 5 per tolah,* to be pounded up and used as *khol* for blackening the eyes of the natives, who call it by the rather loosely-applied name *súrma*. It is also said to occur in the same rock on the right side of Khewra gorge, near a temple. (Dr. Fleming's Report, page 256.)

Alum.

Alum.

The manufacture of alum is not now carried on in the Salt Range proper, but formerly alum was made at a place about two miles westward of Virgal, on the Son-Sakesar plateau, and also beneath Sakesar mountain, at the head of the Âmb glen. In both these places the alum was obtained from the black shales at the base of the nummulitic limestone. It is probable that these would have answered the purpose in other places, but the experiment apparently has not been tried.

Trans-Indus at Kálabágh, and again in the valley of the pass of Chichâli, there are alum works in active operation, the shales being the same as those Cis-Indus. Interesting and detailed accounts of the manufacture of the alum west of the Indus may be found in Dr. Jameson's (page 212) and Dr. Fleming's two reports (pages 522 and 335, respectively). The process appears to be the same everywhere, and is effected thus: A layer of brushwood (Tamarisk or *Dodonæa*) is spread on the ground, on which are placed alternate layers, each about a foot thick, of alum-shale and brushwood. The heap so formed is ignited from below, and fresh layers of shales and brushwood are added above until a large heap in a state of ignition is formed. This is left for several months, and when thoroughly roasted, the red burned shale or *rol* is lixiviated

* This, from local information.

in vats with water. The solution obtained is drawn off and allowed to deposit any mud it may hold. This process is repeated, and then the liquid is boiled with an impure alkaline salt called *jamsan* obtained by lixiviation from *kuller*, the sulphate and carbonate of soda efflorescence so common in the country. It is afterwards allowed to settle and slowly crystallize, the crystals being removed, washed, dried, and melted in iron pans in their own water of crystallization; the fluid is then transferred into earthen ovoid jars for eight or ten days to re-crystallize; after this time the mass, which is generally hollow, is tapped and the uncrystallized alum solution drained off, when the jars are broken and the alum is ready for sale.

This account has been abbreviated from Dr. Fleming's, which, on comparison, was found to possess his general accuracy of observation.

KAHI MITTI.

Kahi mitti.

A shale containing sulphate of iron and alumina, probably from the Chita Wán, near Ghari, in the Salt Range, is mentioned in Mr. Baden-Powell's work already quoted. It is most likely that these shales are part of the soft alum shale group just below the nummulitic beds. At all events, some shales associated with the black alum-shales are said to contain silky crystals of anhydrous protosulphate of iron. The shale is pounded and mixed with the mother liquid from the crystallization of the alum, after which the mixture is allowed to dry in the sun and again treated in the same way, the substance thus obtained assumes a tawny yellow colour, and consists of a mixture of alum and sulphate of iron, the latter largely predominating. This is called *kahi*, and is used in dying leather or cloth grey or black.* The black mud of the sulphurous springs in the Bakh ravine is also used (in this way probably) by dyers.

* Economic Resources of the Panjáb, p. 67. Mr. Baden-Powell (l. c., p. 11) gives the price at 7 tolahs 10 mashas to 10 tolahs per rupee.

Ochre.

In Mr. Powell's book there are several references to ochre from the Salt Range, &c.; the only instance, however, in which the use of any of the ochreous beds of the district came under notice was in the colouring of cotton cloths of a dirty red, by soaking them in the muddy water of pools upon the red ground, formed of the flaggy and shaly group No. 6, in the eastern part of the range, near Sadand, above Jutána.

Gold.

Gold

Gold is washed for in the Indus at Kálabágh, sometimes also in the Bunhár river bed at the other end of the range, and in several small streams along its northern flanks; the present source of the precious metal being the tertiary sandstone formation, and apparently among the beds of the Lower Siwálik group. The process is not continuous, being only carried on after heavy falls of rain in the smaller streams, and in the Indus when floods permit. The amount realised can hardly be closely ascertained, for as the industry is taxed, it is the interest of the operators to conceal their gains. According to the best information obtainable, these fluctuate from 3 to 4 annas worth a day per man, this being generally thought rather above the average measure of success.

Conclusion.

I cannot conclude this record of the results of the examination of the Salt Range without acknowledging the valuable assistance received by the Officers of the Geological Survey, from the Political Officers of the Jhelam and Méawáli districts; from the Salt Department Officers—Mr. Wright, Mr. Matthews, Dr. Warth, Mr. Hickie, Mr. Weldon, Mr. Bolster, and others; as well as from Lieutenant DeWolski, R.E., on duty connected with the wire-rope tramway.

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